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CONFERENCE ON APPLICATION OF PHOTOGRAPHY*

The first symposium of the 1953-4 season, organised by the Scientific and Technical Group of the Royal Photographic Society in conjunction with the Birmingham Photographic Society, took place on Saturday, December 5th at York House, Great Charles Street, Birmingham.

The morning session, under the chairmanship of Dr. G. I. P. Levenson, was opened by Mr. E. H. Cochrane, President of the B.P.S., who welcomed the R.P.S. contingent to Birmingham. Mr. A. G. Tull conveyed a short message of greeting to the Conference from the Council of the R.P.S.

The three morning papers covered, in a general way, three aspects of the Centenary Conference of last September. Mr. R. McV. Weston (Simpl Ltd.) presented a brief account of high-speed photography, starting from the earliest beginnings, and was able to give first-hand appreciations of the problems involved in handling the various types of equipment. He finished by showing an original high-speed film on the working of the non-return trap in a clinical thermometer. The curvatures of the wall of the trap are such that surface tension prevents the flow-past of mercury. When the bulb is heated the pressure rises until it is high enough for a discrete droplet of mercury to be shot through the empty trap to join the end of the column of mercury in the stem of the thermometer. The cycle is then repeated so long as the heating continues.

Mr. A. G. Tull (Technicolor Ltd.) confined his remarks to a digest of the more important papers presented before the Colour sessions of the Centenary Conference. In conclusion he showed the original set of 2 × 2 inch slides, prepared by Mr. Coote, which show the same subject photographed on five commercial colour processes. In answer to a question in the discussion, Mr. Tull confirmed that colour-correcting masks had been used in enlarging the 16mm Kodachrome film of the Everest expedition to make 35mm imbibition prints.

Chief Inspector P. G. Law (New Scotland Yard) gave a brief survey of modern forensic photography, very thoroughly illustrating his points by means of numerous slides from actual cases. The Birmingham Police, it seems, were early in the field, using Daguerrotypes to trace undesirables.

The three papers presented after lunch, with Dr. K. Thompson in the chair, described some of the uses made of photography in the Birmingham district. Mr. S. B. Simcox (Dunlop Rubber Co.) outlined some of the problems of producing 16mm industrial sound films; he emphasised the many advantages, both technical and economic, of using the magnetic sound-stripe process of sound recording, over that of the conventional silver image track. These advantages were of the greatest importance when only a few copies of a film were required; the magnetic process seemed however unlikely to displace the silver image process used for multiple cinematographic release prints.

Mr. H. G. Crabtree (Birmingham Gazette and Dispatch Ltd.) gave a most amusing and informative account of Press photography today. His talk might well be described as a thesis on applied psychology. The press cameraman has to know his Editor, and to know what the Editor thinks the readers want. Any given event can be photographed in more than one way, and Mr. Crabtree brought together many examples showing the differences in the photographic coverage, by various papers, of the same event.

The final item was a fascinating film taken on 16mm Kodachrome by Mr. W. G. Baines, showing the interior of an observation bee-hive, and the activities of its inhabitants. Many of the scenes shown were remarkable; the emergence of a young bee from its waxen cell, and its first attempt to fly—the forcible removal of a dead embryo bee from its sepulchre by the strenuous efforts of two worker bees—the violent dismembering of an unfortunate wasp which had invaded the hive—and the "wiggle dance" of a bee after discovering a store of food. Those and many other interesting scenes composed a notable film on the habits of bees, which formed a fitting conclusion to the day's most successful Conference, in which all six papers were read to a full auditorium.

The theoretical sessions of the Centenary Conference are to be the subject of another one-day Symposium to be held in Oxford during the latter part of March 1954.

* Contributed on behalf of the Royal Photographic Society of Great Britain, Scientific and Technical Group, by G. I. P. Levenson. Received 15 December 1953.

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A CATHODE RAY OSCILLOGRAPH TESTER FOR FOCAL PLANE SHUTTERS

Henry Wallman*

ABSTRACT

A simple and versatile apparatus is described for the oscillographic testing of focal plane shutters. Curves of light vs. time are displayed on the cathode ray oscilloscope screen, from which total exposure time, effective exposure time, and efficiency can be read off. Shutter calibration accuracy and evenness of exposure time across the film plane can be investigated. Each measurement takes only a few seconds and, at the medium and higher shutter speeds, it is even possible to obtain exposure curves at the left end, the middle, and the right end of the film plane with a single actuation of the shutter.

THE INTRODUCTION of oscillographic technique for the testing of camera shutters appears to date from 1931,[1] but the method really became practical with the use by Kelley[2] of cathode ray tubes having long-persistence screens. Katz[3], describes the wide employment of cathode ray oscillograph technique for testing central shutters (between-the-lens shutters) during the war at the USAF Photographic Laboratory at Wright Field. The work led in fact to the adoption of the C.R.O. method in the American Standard for testing central shutters.[4]

For focal plane shutters, however, the methods recommended by Katz are not oscillographic but photographic-mechanical[5], involving either a stroboscopic lamp or a rotating drum.[6] The drum method involves—for each shutter-time setting—wrapping a photographic film inside the drum (in darkness), bringing the drum up to known speed, exposing and developing the film, and then interpreting the record. The method is plainly too cumbersome to be employed for routine testing.

The taking of high-speed motion pictures of the shutter constitutes a superlatively informative procedure, but it is an even more expensive and time consuming method.

Tester for Focal Plane Shutters in Amateur Cameras Taking Pictures Up to 2¼ in. Square

It is the purpose of this note to describe an extremely simple and flexible apparatus for the rapid and accurate cathode-ray oscillographic testing of focal plane shutters. The method has been employed since 1952 at Chalmers University of Technology. The unit described in this paper is intended and has been used for testing focal plane shutters on "miniature" cameras (negative sizes up to and including 2¼ inch square), but only slight mechanical modifications would be needed to permit the investigation of shutters of larger size. Despite its speed and simplicity the apparatus permits the measurement not only of effective exposure time, but also of shutter efficiency and evenness of exposure time over the film plane.

For the purposes of the University's teletechnique laboratory, where the need for testing shutters is only occasional, it was felt desirable to arrange the apparatus in the form of a main unit capable of being coupled, as needed, with the laboratory's already existing standard electronic equipment. Very little more than a single type 931-A photomultiplier tube is permanently committed to the shutter tester. If, on the other hand, the method were to be used for continuous production-line quality control, it would of course be appropriate to combine the various units into a single self contained instrument.

Description of the Apparatus

The back of the camera under test must first be taken off. This is a trivial operation for most focal plane cameras, but requires removing four screws in the Leica camera.

The main part of the tester consists of a 5×5×2½ inch box incorporating a thin brass plate which lies in the film plane of the camera and has three pinholes disposed along the direction of shutter travel. A slide arrangement makes it possible to cover any combination of these pinholes. See Figure 1. The box contains in addition only the following: a type 931-A multiplier phototube with voltage divider for the phototube dynodes, a simple optical arrangement for concentrating the light through the pinholes onto the photocathode, a two-position switch: "Timing marker-Phototube," and various cable connectors.

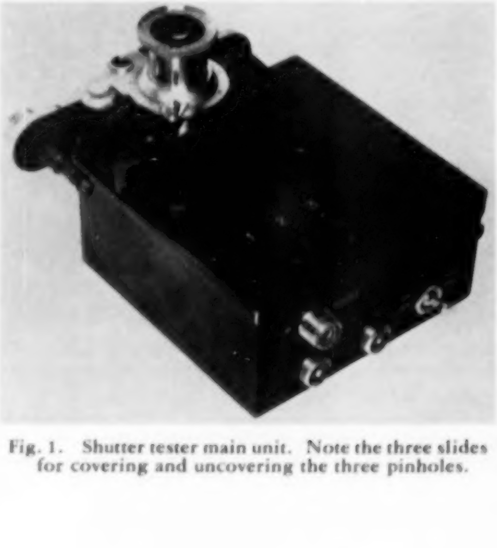
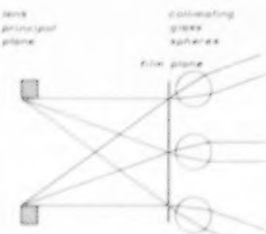


Fig. 1. Shutter tester main unit. Note the three slides for covering and uncovering the three pinholes.

* Chalmers University of Technology, Gothenburg, Sweden. Received 19 October 1953.

Fig. 2. Shutter tester ray diagram: 5 cm lens, f/1.5 aperture. After the light bundles are collimated by the small glass spheres, they are reflected by mirrors, not shown, onto the photocathode of the type 931-A photomultiplier.



The light bundles from the camera lens opening passing through the pinholes are strongly divergent, especially at large lens apertures, such as f/1.5. Glass spheres of about 11 mm diameter, and of no particular precision of manufacture, are therefore used to refract these divergent bundles into parallel bundles, and these collimated rays are then reflected by small mirrors onto the photocathode. Figure 2 shows a ray diagram for the case of a 24×36 mm negative with a 5 cm lens at aperture f/1.5, and Figure 3 is a photograph of the interior of the main unit, showing its simple construction.

If only effective exposure times are to be measured, the camera lens should be stopped all the way down, as discussed below in the section on Efficiency. In that case the collimating spheres are unnecessary, only the small mirrors being required. Some thought was given to the use of a type 5819 photomultiplier tube, which has a considerably larger photocathode than the type 931-A. The idea was not pursued, however, principally because of the fact that although the collimating spheres would be unnecessary for 24x36 mm picture size cameras with a type 5819 phototube, the spheres would be necessary for cameras taking 2¼ inch square pictures. A type 5819 tube costs \$55, moreover, as compared with \$9.75 for a type 931-A.

The rest of the tester consists of standard electronic apparatus connected to the main unit as the occasion for shutter testing arises, namely a cathode ray oscillograph with suitable sweeps and long persistence screen (the Tektronix type 512, with P7 screen, is excellent), an audio-frequency generator for the time markers, and a -1000 V supply (non-regulated) for the photomultiplier.

The pinhole diameter is slightly less than 0.2 mm. Pinholes are preferable to slits, both because pinholes are easier to make and because use of slits would involve a risk of non-parallelism with the moving gap in the focal plane shutter. The brass plate bearing the pinholes is 0.1 mm thick, and is backed up with a thicker and more rigid plate containing larger holes, against which the slides run. It is important that the pinholes lie accurately in the film plane, and some attention must be devoted to avoiding light leaks.

The light source should be of uniform brightness, large angular extent, and free of "hum." Best and simplest is the clear daylight sky, or sunlight reflected from a white projection screen. Failing this, use can be made of an ordinary electric lamp by resting a milk- or opal-glass sheet directly over the camera lens. The lamp-to-lens distance will vary from two inches to two feet, depending on the aperture. AC operation of the lamp yields about 15 percent "hum", at twice line frequency. Such a "hum" component can only be tolerated at the highest shutter speeds; for slower speeds DC lamp operation is therefore required.

Although the image-forming properties of the lens are of no importance in these investigations, the camera lens should be left in place, since its iris diaphragm is needed. For production-line testing it might be cheaper to use a lens mount with iris diaphragm but without lens, or better, with lens replaced by a disk of opal glass.

A block diagram of the shutter tester is shown in Figure 4. In the simplest mode of operation of the apparatus, one of the pinholes is left open while the other two are closed. When the shutter is tripped, the moving gap of the shutter permits light to pass through the open pinhole. The light flux is a function of time and is converted by the photomultiplier to a time-varying voltage. This voltage is connected to the cathode ray oscillograph so as to initiate (trigger) the horizontal sweep of the C.R.O. spot, i.e., the sweep starts very soon (less than 50 microseconds) after the shutter begins to let light through to the photomultiplier. The sweep time-duration has previously been set to a value slightly larger than the expected exposure time. The photomultiplier voltage is also applied to the vertical deflection plates of the C.R.O. and the trapezoidal curve drawn on the oscillograph screen is thus clearly proportional to the light flux, as a function of time, permitted to pass through the pinhole by the shutter. We obtain, in other words, a curve displaying the entire shutter exposure process, in its opening, fully-open, and closing phases. The synchronization is effected by the light flux itself, and there is no mechanical connection between the shutter and the oscillograph.

Measurement Methods

Three measurement methods have been developed, of increasing convenience but decreasing range of applicability (the later methods are suitable for the shorter exposure times only). With the oscillographic apparatus fully set up, a few seconds suffice to change from the one method to another.

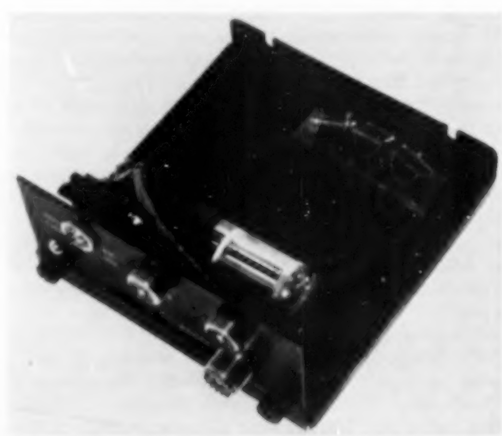


Fig. 3. Inside of shutter tester main unit. The collimating glass spheres, which lie in the tubes under the small mirrors, are not visible in this photograph.

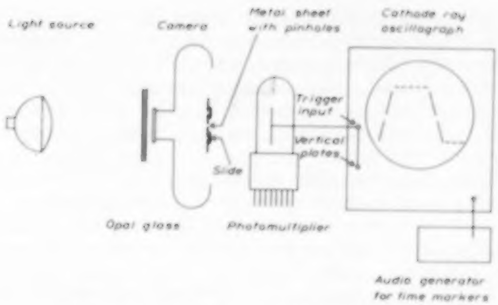


Fig. 4. Block diagram of shutter tester.

Single pinhole-single sweep method—In the first method, denoted the single pinhole-single sweep method, only one pinhole is left uncovered at a time. The procedure, which is that described immediately above in connection with Figure 4, is suitable for all exposure times, both short and long. Each measurement takes only a few seconds, and the pinhole slides permit rapid investigation of the exposure time, for each shutter time setting, at each of three positions in the film plane.

The curves are timed—in order of increasing accuracy— by a) relying on the sweep speed calibration of the oscilloscope, b) calibrating these sweep speeds in advance of a measurement series with the audio generator, c) making use of the screen persistence to impress a separate timing wave, or timing dots, on the screen after each exposure curve, or d) injecting timing blanking-pulses onto the C.R.O. intensity grid.

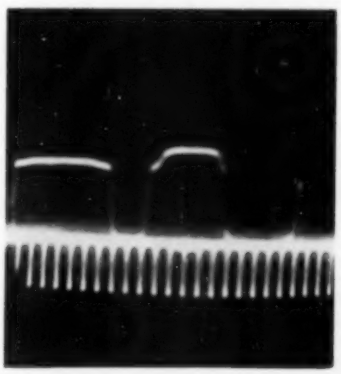


Fig. 5. Triple pinhole—single sweep trace. Shutter setting = 1/250 s, time markers = 1 ms, actual exposure times = 7, 6, and 1 ms.

Triple pinhole-single sweep method—The second measurement arrangement, called the triple pinhole-single sweep method, differs only in that all three of the pinholes are left uncovered. The sweep time is made somewhat larger than the total travel time of the shutter across the film plane. A trace of this type is shown in Figure 5. The time durations of the three curves, 7, 6, and 1 milliseconds, are the exposure times at the corresponding pinholes. In Figure 5 the approximate equality in spacing between the initial points of the partial traces shows that the shutter in question moves with rather constant velocity. We note that because of varying shutter gap width there is, however, a large variation in exposure time at the various pinhole positions.

At the medium and high shutter speeds (1/200 second or shorter) the exposure curves for the three pinholes are fully separated (see Figure 5). At the slower shutter speeds, however, the shutter uncovers more than one pinhole at a time, and the three exposure curves overlap. The resulting ascending and descending staircase curve is rather difficult to interpret, so that the triple pinhole-single sweep method is, in practice, limited to shutter speeds faster than about 1/200 second. This is a disadvantage compared with the single pinhole-single sweep procedure, but within its range of applicability the method has the great advantage (in common with the other triple pinhole method, below) of yielding almost all practically useful shutter information, namely the exposure curves at the left end, the middle, and the right end of the film plane, with only a single shutter release per shutter time setting.

The warning must be given that the method is inapplicable if the shutter does not have a constant slit width and if its operation is so bad as to be completely closed when it passes one of the pinholes, for there are then only two partial traces and it may not be clear to which pinholes they correspond.

Triple pinhole-triple sweep method—By means of a vertical sweep unit with sweep time slightly exceeding the total shutter travel time across the film plane, the exposure curves in the triple pinhole case can be separated into three parallel sweeps, as shown in Figure 6. The exposure curve pertaining to pinhole 1 starts at the lower left hand corner, the curve for the middle pinhole begins higher up, and the curve for pinhole 3 is that starting highest. The fact that the middle curve in Figure 6 has largest amplitude has no significance in the testing of shutter exposure time, and indicates only that the light flux is greatest at pinhole 2. A triggered vertical sweep unit can be built simply or another C.R.O. can be pressed

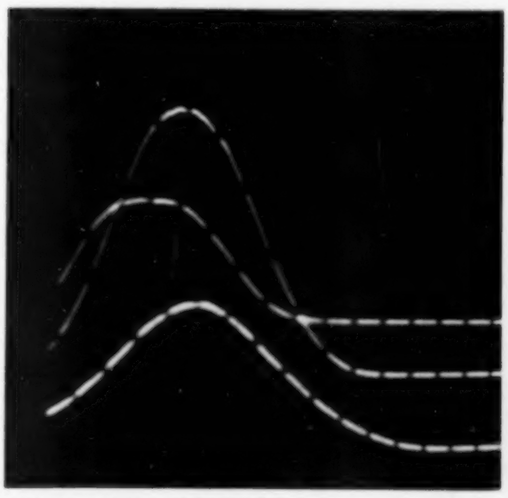


Fig. 6. Triple pinhole-triple sweep trace. Shutter setting = 1/1000 s, aperture = f/1.5, time markers = 0.2 ms. Actual exposure times are close to 1.2 ms for all three pinholes. These curves represent by far the best results obtained in our measurements of focal plane shutters, but the same camera was very poor at +5 F (see Fig. 10).

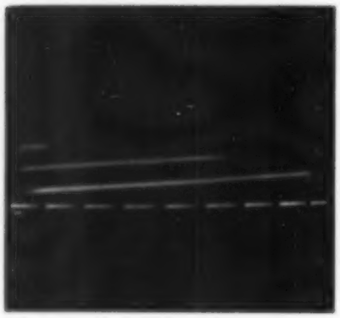


Fig. 7. Intensity modulation trace, triple pinhole-triple sweep. The lengths of the sloping lines are measures of the exposure times at the corresponding pinhole positions. Same shutter setting, time marker intervals, and actual exposure times as in Fig. 5.

into service as sweep generator. The horizontal sweep in this method is set, as in the single pinhole case, to a time slightly exceeding the expected exposure time.

Compared with the triple pinhole-single sweep method, the triple sweep display is easier and quicker to read and probably more adapted to production-line "go—no go" testing. Its range of usefulness is, however, restricted to times of 1/500 second or shorter, in accord with the following remark: Let t_1, t_2, t_3 be the exposure times at pinholes 1, 2, 3, let T_{12} be the time of travel of the shutter from pinhole 1 to pinhole 2, and T_{23} from pinhole 2 to pinhole 3. Then the criterion for applicability of the triple pinhole-triple sweep method is that the largest of t_1, t_2, t_3 be less than the smaller of T_{12} and T_{23}. In miniature cameras the usual shutter travel time across the whole film plane is about 25 milliseconds. For such shutters the criterion above would be satisfied for an exposure as long as 1/100 second, provided the curtain velocity and gap width were constant and the gap width were correct. The criterion is very sensitive to variability in curtain velocity and gap width, however, and this, together with the speed tolerances found in commercially available miniature camera shutters used for pictorial photography, explains why the triple pinhole-triple sweep method is in practice likely to be useful, as already stated, only for exposure settings faster than 1/500 second.

Intensity Modulation Methods

Deflection modulation was used in all the preceding displays, but intensity modulation can also be employed (see Figure 7). In this figure there is a sloping line-interval for each pinhole and the time duration of each interval is the exposure time corresponding to that pinhole position. Information is lost, however, since the opening, fully-open, and closing phases of the shutter exposure process are no longer separately displayed. Measurement errors of up to several hundred percent are possible, moreover, except for the case of very high shutter efficiency (90 percent or more—at the highest shutter speeds this can in practise only be achieved by closing the lens aperture down to f/22 or smaller). At lower efficiencies the measured exposure time, i.e. the length of the intensity-modulated trace, will depend critically on how high up on the sides of the trapezoidal exposure curve one places the trace-brightening threshold level. In the case of an exposure curve corresponding to 60 percent efficiency, for example, the top of the trapezoid has five times smaller time duration than the base. The problem of where to place the threshold level is further aggravated by the fact that the heights of the individual exposure curves vary between extremely wide limits from case to case, depending as they do on f-number, brightness of light source, evenness of light source, $\cos^4$ law, and vignetting.

A non-oscillographic method which has been used for shutter testing consists of electronically closing the connection between a constant-current source and a condenser during the leading edge of the photomultiplier output curve and opening the connection during the trailing edge; the charge on the condenser can then be indicated on a voltmeter as a measure of the exposure time. The method clearly suffers all the above disadvantages of the intensity-modulation oscillographic method, plus the disadvantage mentioned in the last sentence of the section below on "Constancy of speed from exposure to exposure."

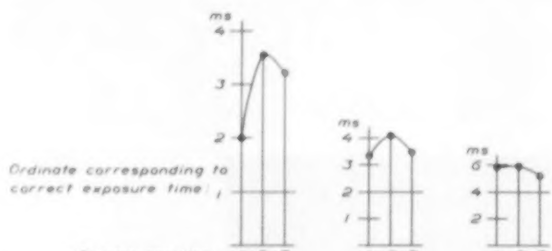


Fig. 8. The circled points are measured exposure times at the three pinhole positions, for the shutter settings 1/1000 s, 1/500 s, and 1/250 s. The measured average exposure times are 2.9, 3.6, and 5.5 ms.

Shutter Characteristics Measurable by the Apparatus

Calibration accuracy—An example of a measurement series is shown in Figure 8. Averaging the three exposure times at the three pinhole positions permits evaluation of the calibration accuracy of the shutter markings. Note that at the 1/1000 second setting the shutter of Figure 8 displayed an actual average time of 2.9 milliseconds.

Evenness of exposure across the film plane—Neither curtain gap width nor curtain velocity need be constant in an ideal shutter, but their quotient, that is, exposure time, should be constant. The example illustrated in Figure 5 shows an *exposure-time ratio*, defined as the ratio of maximum to minimum exposure time across the film plane, equal to 7 at a shutter setting of 1/250 second. In other words, one point of the negative is exposed 7 times as long as another. (Observe that the use of only three measurement points flatters the shutter, insofar as exposure-time ratio is concerned.)

Constancy of speed from exposure to exposure—Figure 9 shows the traces from ten exposures in rapid succession at a fixed time setting. The observed variation in exposure time, presumably due to varying spring tension,

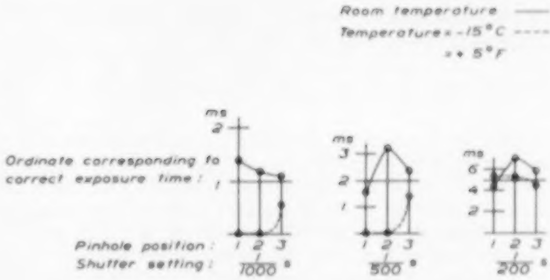


Fig. 10. The circled points are measured exposure times at two temperatures. Note that at +5 F the shutter entirely fails to open over half the negative length, at the two fastest shutter settings.

is about 20 percent. This variation is photographically negligible, but its existence must not be ignored in comparing exposure time at different points in the film plane. If an accurate comparison is required one should employ a triple pinhole method, or, if the single pinhole method is used, the results of three or four shutter actuations at each pinhole should be averaged. This need for carrying out about 10 shutter actuations per time setting is a weakness of the single pinhole method in examining evenness of exposure over the film plane.

Low-temperature performance—For several of the cameras a complete series of measurements was made at room temperature, 20 C (68 F), and at a not-too-extreme winter temperature, −15 C (+5 F). Some partial results are presented in Figure 10, and show that the shutter speed variation between the two temperatures can be large when the mechanisms have not been specifically lubricated for low temperature operation. Similar investigations could be carried out for conditions of high temperature, high humidity, etc.

Efficiency—In the cone of light rays converging from the lens opening to a given point in the film plane, each individual ray evidently contributes to the exposure of the negative during a time equal to W/V, where W is the curtain gap-width and V the curtain velocity at the point in question.[7] The effective, or negative-darkening, exposure time is thus

$$t_{eff} = W/V, \tag{1}$$

regardless of the f-number N or the distance d between film plane and shutter plane.[8] The diameter of the light cone in the shutter plane is clearly d/N, and hence the total, or motion-stopping, exposure time is

$$t_{tot} = [W + (d/N)]/V. \tag{2}$$

The ratio t_{eff}/t_{tot}, the efficiency E of the shutter, is thus

$$E = \frac{t_{eff}}{t_{tot}} = \frac{W}{W + (d/N)}. \tag{3}$$

In the usual case in which the light cone is narrower than the curtain gap, i.e., $d/N < W$, so that some part of the curve of light flux vs. time is flat, it can be shown that t_{eff} is the time interval between points half way up the exposure curve, or equivalently the efficiency is the ratio of the area of the whole exposure curve to that of the rectangle with base t_{tot} and the same height. (Following usual practice, exposure time in this paper denotes effective exposure time unless total exposure time is specifically mentioned.)

Figure 6 shows oscillographic curves at three points in the film plane of a certain miniature camera, at a time setting of 1/1000 second and aperture f/1.5. It is seen that the efficiencies are 50 percent, 50 percent, 70 percent. The greater efficiency at the last pinhole is due to a larger gap width W, representing automatic compensation in this camera for increasing curtain velocity, together with a smaller film-plane to shutter-plane distance d at that end of the film plane.

The simplicity of formula (3) has led to the assertion that no test equipment other than a machinist's scale is needed to determine efficiency. The statement is valid for shutters of the Graflex type, which have fixed slits, but does not hold for certain modern small cameras. Determination of d and N is trivial, but W, which is the gap between two moving curtains, is not easy to measure, and may well vary over the film plane. The measurement of efficiency is in fact a rather difficult task, best accomplished by the oscillographic technique described above.

Once E is known one can, if desired, work back from formula (3) to determine W and then from (1) to determine V. For a given shutter setting the efficiency can evidently be determined at any lens aperture if it is known at any other.

Formula (3) shows that efficiency increases—the exposure curve becomes squarer—as the lens is stopped down or the exposure time increased. This is illustrated in Figure 11; the increase in efficiency is, as we see, not very rapid.

Because of the non-zero size of the pinholes the exposure curves drawn on the oscillograph will not be absolutely square even if the shutter efficiency were 100 percent; with pinholes of diameter less than 0.2 mm the correction is however unimportant even at the highest shutter speeds.

It is interesting to recast formula (3) as a function of N only, that is to investigate efficiency, at a fixed point

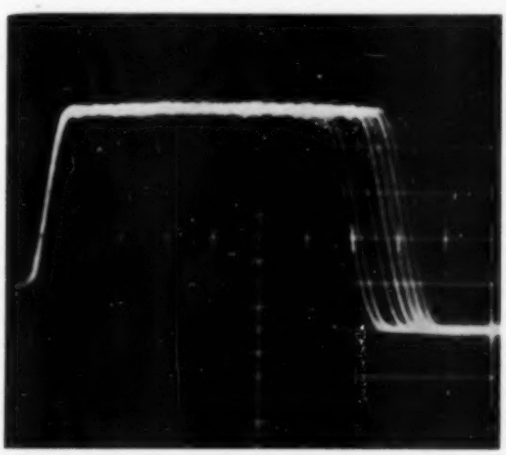


Fig. 9. Exposure curves for ten consecutive shutter actuations. Shutter setting = 1/1000 s, 1 horizontal division = 0.2 ms.

in the film plane and fixed time setting, in terms of varying lens opening. The result is that

$$\frac{1}{E} - 1 \text{ is proportional to } \frac{1}{N}. \qquad (4)$$

The result corresponding to (4) for central shutters is that $1 - E$ is proportional to $1/N^2$ (see Katz, ref.[3], eq. (7)). We note that efficiency increases with N much more rapidly for central shutters than focal-plane shutters. Thus to increase efficiency from 50 to 87 percent the lens has to be closed down two stops with a central shutter and almost six stops with a focal-plane shutter.

A practical consequence of (4) is that if only t_{eff} is to be measured for a focal-plane shutter, the lens should be closed down all the way, to f/16 or f/22. The efficiency is then likely to be about 90 percent even at the highest speeds, and the estimation of what is half way up on the exposure curve becomes extremely non-critical.

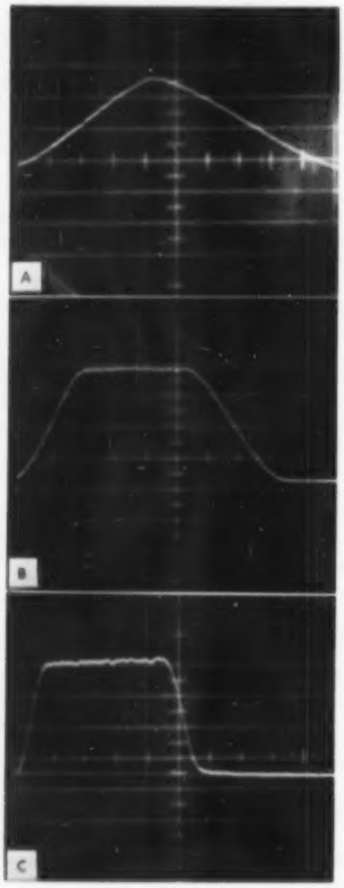


Fig. 11. Exposure curves showing increasing efficiency at decreasing aperture (shutter setting, 1/1000 s, one horizontal division = 0.2 ms.):
(A) f/1.5, efficiency = 50 percent,
(B) f/3.5, efficiency = 70 percent,
(C) f/16, efficiency = 85 percent.

Results and Comments

Each of the better known types of 35 mm and 2¹/₄ inch square cameras with focal plane shutter was represented, in general with several samples, in tests carried out with the oscillographic shutter tester. The cameras represented three countries of origin; about half were brand new and directly obtained from camera shops, and the others were at most a month or two old with the exception of one camera which was four years old. Although the shutters were not badly discrepant at times of 1/200 second or longer, at higher speeds large errors in calibration or large unevenness of exposure time appeared to be the rule. A shutter setting marked 1/500 second could be expected, in our experience with these cameras, to be no faster than 1/300 second, and a position marked 1/1000 second could well be 1/400 second or even longer. Large exposure-time ratios were encountered also: in many cases some parts of the film plane were exposed three times as long as others. There were some instances in which the shutter was completely closed over some part of the film plane. Test exposures made to check these cases showed, as expected, blank strips on the negative.

The focal plane shutters installed in the miniature cameras described above offer advantages over central shutters in the facility they allow for lens interchange but their claim to shutter speeds of 1/1000 second and faster could not be substantiated in our tests. The disadvantage of exposure-time variation over the film plane displayed by many focal plane shutters in the miniature cameras we tested is excluded in the case of cameras with central shutters, since such shutters automatically expose all points of the film plane for equally long time intervals. Central shutters do not introduce distortion of rapidly moving objects, as focal plane shutters do, and, above all, central shutters are much easier to synchronize for flash—focal plane shutters are indeed inherently incapable of being synchronized for electronic flash except for settings in which the shutter is wide open, that is to say, for settings longer than about 1/40 second.

Good central shutters, meeting the requirements of American Standards, must operate within 20 percent of their effective exposure time markings at 1/100 second or slower and within 30 percent at greater speeds. In a series of articles[9] on the construction of a well-known miniature camera with focal plane shutter it is asserted that the manufacturers aim to hold timing errors at the higher speeds to 40 percent. Only one of the ten focal plane shutters we tested fell within this 40 percent tolerance, and at a temperature of +5 F this same shutter was very poor. It was, in fact, completely closed over more than half the length of the negative at this temperature, at both the 1/1000- and 1/500-second settings.

The most accurate shutter we encountered, irrespective of type, was an American-made central shutter of recent design. This had marked speeds from 1 second to 1/800 second and C.R.O. measurement showed the calibration to be accurate within 20 percent over the entire range, including a very exact 1/800-second setting. Although of the central type, this shutter was slightly faster than the fastest focal plane shutter tested, and was much faster than most. It is the author's opinion that the excellent

performance of this shutter must be attributed in large part to the fact that the makers systematically employ C.R.O. technique for examining their product during manufacture. It is further the author's opinion that C.R.O. techniques applied to the production testing and associated quality control functions in the manufacture of focal plane shutters will result in performances more in line with the shutter speeds marked on the shutters of these miniature film cameras.

Acknowledgment

It is a pleasure to acknowledge the painstaking assistance of Messrs. Robert Magnusson and Nils Stålberg.

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A POROUS-PLATEN PROCESSOR FOR PROCESSING PHOTOGRAPHIC MATERIALS IN ROOM LIGHT

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ABSTRACT

Simple equipment is described for processing certain types of photographic papers in normal room illumination. It consists of a high-intensity printer, a solution, applicator sponges, a porous processing platen, and a windshield wiper blade, all contained in one legal-size letter file drawer. The two processing solutions are applied with the sponges while the paper is held in contact with the porous platen. A satisfactory platen for processing a number of prints can be made simply and inexpensively from plaster of Paris.

For many years the contact-printing type of photographic papers made for the reproduction of documents were used only where darkroom facilities were available. The introduction of papers which could be handled in room light eliminated the need for a darkroom for some specific applications. In 1952, several contact-printing transfer processes which did not require rinse water were announced for copying documents in an office in room light. These processes make use of a special type of sensitized paper and processing solution. There are also conventional types of photographic papers which can be handled in room light. Kodagraph Autopositive Paper, for example, is now used extensively as a high-contrast positive or as an intermediate from which photographic or diazo reproductions can be printed. Kodagraph Repro-Negative Paper, another product to be handled in ordinary room light, produces high-contrast negatives by reflex or print-through exposure for making intermediates for printing offset plates and other types of sensitized materials. However, if the usual processing procedure is followed, the paper must be fixed and washed thoroughly to remove the chemicals and to assure a permanent record. Washing saturates the paper and necessitates a time-consuming drying step which somewhat limits the use of conventional processing for small-scale document reproduction. However, if a permanent record is not required, it is possible to confine the solutions to the sensitive surface of the paper and to eliminate the washing and drying steps altogether.

A surface application method is described in this paper for processing copies of letters, pages from periodicals, business forms, etc., in a minute or less. The operations may be performed in ordinary room light and without the use of rinse water. The prints have reasonable stability for short-term use and are sufficiently dry after the one-minute processing step to be handled or folded immediately for mailing. The entire unit, including printer, processor, and storage place for extra chemicals and paper, is contained in one drawer of a legal-size letter file (Figure 1). The paper is processed by the stabilization method.[1]

Photographic papers are usually processed by immer-

[1] Russell, H. D., Yackel, E. C., and Bruce, J. S., "Stabilization Processing of Films and Papers," *PSA Journal, Section B* (Phot. Sci. and Technique), *16B*, pp. 59–62, August 1950.

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sion in the processing solution. After development, the unexposed and undeveloped silver halide is converted to soluble silver salts in a fixing bath containing hypo, and both the silver salts and the hypo are washed from the paper in water. When processing with a stabilizing solution, the image is developed in the usual developer, but a "stabilizing" solution replaces the standard fixing solution. The stabilizing bath converts the undeveloped silver halide of the emulsion to a moderately stable silver complex that is not washed from the paper and which is fairly resistant to fading or staining under normal storage conditions. It is well to remember that the undissolved colorless halide may eventually discolor the paper and that the hypo in the stabilizing bath which is not washed from the paper tends to bleach the silver image in time. On the other hand, under favorable storage conditions, some types of stabilized prints may last for years. Another point to bear in mind is that after the stabilized print has been used for the purpose for which it was immediately intended, it can be fixed in a conventional fixing bath and washed in the normal way. The life of such a print would then be comparable to that of conventionally processed photographic print. Although a stabilized print is by no means as permanent as a thoroughly washed print, it may nevertheless retain its legibility and serve a useful purpose for a period of years, even though eventually the background may stain and the image may fade.

Stabilization processing may be done in a number of ways, such as by immersion of the print in the bath or by applying the solution to the print surface. Surface application of the solutions offers several advantages, namely, simplicity of operation, minimum amount of processing solution, and rapid drying. Surface application is accomplished in the process described here by applying the solutions with sponges to the emulsion while the paper is held in contact with a porous platen, as

Fig. 1. Complete unit showing printer and processing apparatus.

illustrated in Figure 2. The essential equipment consists of a printer of adequate intensity for exposing paper to be handled in room light, two solution reservoirs, two applicator sponges, two windshield wiper blades, a pencil with a rubber eraser, blotters, and a porous platen (Figure 3).

A suitable solution applicator, shown in Figure 3, can be made from a Du Pont viscose sponge shaped on a band saw and coated with colored plastic to form a hard, durable handle. The uncut sponge is approximately 2 by $3^3/_4$ inches by 6 inches, a size commercially available. Smaller sponges are not as satisfactory because they do not permit uniform application of the solutions over the entire sheet during the brief processing period. The developer sponge handle is coated with red plastic and the stabilizer sponge with blue plastic. The sponges fit snugly in their stainless-steel containers, serving somewhat like stoppers for bottles, to prevent excessive evaporation and accidental spillage.

The solution reservoirs, shown in Figure 3, are flanged approximately one inch from the bottom, so that the sponge just touches the solution. Wire mesh is welded onto the sloping back so that excess solution can be

Fig. 2. Technique of holding paper and applying solution.

squeezed from the sponge. This prevents too much solution from being applied to the paper and also avoids dripping the solution on the surrounds. Actually, only about 10 cubic centimeters of each solution are used for processing an $8^1/_2$- by 11-inch sheet.

The windshield wiper blades (Figure 3) are fitted to handles which are also colored red and blue for identification. Two are required for squeegeeing the excess developer and stabilizing bath from the paper. One alone cannot be used because the combination of developer and stabilizing bath on a wiper may produce chemical fog in the emulsion in the form of gray streaks.

A variety of porous materials have been tried on which paper can be processed. Photographic blotters are moderately successful, but they deteriorate rapidly with use. Plaster of Paris is quite satisfactory in many respects, particularly because of the low material cost and the simplicity of making a platen. A block 11 by 15 inches, 1 inch thick, is suitable for processing the standard $8^1/_2$- by 11-inch document and can easily be prepared. A piece of glass, 7 by 9 inches, approximately $^3/_{32}$ inch thick, is embedded flush with the top of the platen to help hold the paper in place during the processing step.

A platen of this type is made by pouring the wet plaster mixture in a mold placed on a plate glass, which is somewhat larger than the mold. The smaller piece of glass is positioned in the center of the mold on the plate glass, as illustrated in Figure 4. A number of sheets of paper can be processed on the plaster of Paris platen before it loses its porosity.

Special ceramic porous "bats" which are highly satisfactory and capable of absorbing the solutions from many pieces of paper were made by the Pass and Seymour Company, Inc., Solvay Station, Syracuse 9, New York, with the cooperation of F. P. Hall. A 7- by 9-inch area of the top was glazed to provide a smooth surface to which the paper would adhere during the processing steps. The useful life of the "bats" can be extended by periodically washing out the absorbed chemicals with warm water. Although the absorption rate of the ceramic platen is somewhat lower than that of the plaster of Paris, it is more satisfactory because of its substantially longer life.

For developing the paper, Kodak Dektol or Kodagraph Developer used full strength is recommended. Depending on the frequency of processing, the solution can be left in the reservoir for several days and replenished to maintain a fairly constant volume until it becomes exhausted or discolored. The stabilizer bath is essentially a non-hardening bath. A suitable formula for use with the papers recommended is:

KODAK STABILIZING BATH FOR PHOTOGRAPHIC PAPER, S-2

	Avoirdupois, U.S. Liquid	Metric
Water	25 ounces	750 cc
Kodak Sodium Sulfite, desiccated	1/2 ounce	15.0 grams
Kodak Sodium Bisulfite	1 1/2 ounces	45.0 grams
*Kodak Sodium Thiosulfate (Hypo)	8 ounces	240.0 grams
Water to make	32 ounces	1 liter

* NOTE: The concentration of hypo may be varied from 4 ounces to 16 ounces per quart of solution (120 to 480 grams per liter) according to the conditions of use.

In practice, this bath is also replenished to maintain the solution level and is discarded whenever the developer becomes exhausted and is replaced. The sponges are rinsed each time new solutions are required. However, it is not necessary to remove them from the solutions

Fig. 3 Essential parts of the processor: platen, reservoirs, sponges, wipers, erasure pencil.

Fig. 4. Making the platen. Plaster is poured in mold over glass plate positioned in the center on larger glass plate on which mold fits.

as they are not affected by prolonged immersion in the developer or in the stabilizer baths.

The actual processing of a piece of paper is fairly simple. Although the first few attempts to hold the paper in place while it is wiped with the sponges may seem awkward, an untrained operator usually finds that, after one or two trials, the paper need be held in place on the platen with the rubber-tipped pencil only for the first few seconds. It is essential that only the inclined edge of the sponge be applied to the paper and that the direction of the brushing be approximately from the center to the end of the paper, overlapping at the center with each stroke. The sponge is inclined always so that one edge is used for one direction and the opposite edge for the other, and the motion is in the direction of inclination. It is equally important that a very light pressure be applied to the sponges and that the entire emulsion be brushed, particularly the corners. The technique is somewhat similar to applying paint with a large brush: the pressure is not downward but toward the ends of the paper, as illustrated in Figure 2. A rapid and uniform wiping or brushing action with the sponges, a form of agitation which accelerates development and stabilization, is necessary to achieve uniform results.

The following procedure is suggested: Moisten the platen with water if it is thoroughly dry. A damp platen will reduce the tendency of the paper to curl and will facilitate holding it in place while the solutions are being applied. Place the exposed piece of paper between moist photographic blotters for 10 to 15 seconds. After the sponge has been removed from the developer reservoir, press it firmly against the inclined screen until the developer no longer runs from it. Place the exposed sheet of paper on the platen, holding it at one end with the pencil eraser. Rapidly brush the sponge over the surface from the center of the sheet toward the opposite end, making several rapid applications to moisten the emulsion thoroughly and uniformly. Move the eraser to the end first brushed, and quickly apply developer, brushing from the center to the dry end. Repeat the cycle as rapidly as possible for approximately 20 seconds, or until the image is fully developed. Replace the sponge in the developer reservoir and wipe the excess

developer solution from the paper with the developer wiper blade. This is done by holding one end of the paper with the eraser and lightly squeegeeing the solution to the opposite end. Shift the pencil to the other end of the paper and repeat the operation. Take the stabilizer sponge from its reservoir and, after squeezing the excess from the sponge on the inclined screen, touch the sponge with the eraser to neutralize the developer on it, and quickly apply the solution to the entire emulsion surface of the paper. This operation must be done as rapidly as possible to prevent streaks from forming. The simplest way to avoid the formation of streaks is to hold the paper at one end with the eraser and quickly, but lightly, brush toward *the opposite end*, first one end, and then the other, shifting the pencil to the opposite end each time. Continue the application of stabilizer for approximately 20 seconds. Replace the stabilizer sponge in the reservoir and squeegee the excess solution from the surface with the stabilizer blade. Two complete strokes in each direction are usually sufficient to remove all of the surface solution completely. Cover the processed print with a dry blotter and press it firmly in contact with the paper. The stabilized print is then finished and ready for use.

Although different types of photographic material can be processed on a porous platen, it is intended primarily as a device for processing paper in room light and without the usual darkroom facilities.

The photographic papers mentioned can be handled and processed on the porous platen in room light by working rapidly so that the paper is exposed to the ambient light for the minimum time consistent with good technique. The term "room light" is somewhat indefinite. As used here, it applies to those work spaces where the predominant illumination is obtained from tungsten lamps and does not exceed an intensity level of from 10 to 15 foot-candles, as measured with a light meter. Daylight and fluorescent illumination are to be avoided, because both these sources of illumination are rich in actinic light and will fog most types of sensitized photographic materials. It is recommended that safe illumination conditions be established by making a test in the working area. To test Kodagraph Autopositive Paper, expose a sheet of it in contact with an original for a time which is known to give a satisfactory copy, then develop it for the recommended 20 seconds on the porous platen and stabilize it, shielding the paper as much as possible from direct light. An absence of fog indicates a safe working condition. Kodagraph Repro-Negative Paper should be processed under the same conditions but *without a printer exposure*. The processed sheet should be white. Kodagraph Autopositive Paper, Extra Thin, and Kodagraph Autopositive Paper, Translucent, both have the unique property of producing excellent-quality high-contrast positive reproductions from positive originals when developed in the normal way and fixed either in the usual manner or stabilized according to the procedure described here. Kodagraph Autopositive Paper, Extra Thin, is suitable for reproducing a single-sided original in one step by the print-through method. An original printed on both sides requires a reflex exposure and, since this produces a mirror image, a second print is made, using either Kodagraph Autopositive Paper, or as is often done, diazo or blueprint paper. When a reflex-exposed print is to be used as an intermediate for diazo printing, Kodagraph Autopositive Paper, Translucent, is more generally used, because the higher transmission of this material permits high printing speeds in the diazo printing operation.

For making intermediate negatives which can be processed on the porous platen in room light, Kodagraph Repro-Negative Paper is used. This paper is exposed either by the print-through method or the reflex method, and is a satisfactory negative material for printing photographic copies or sensitized offset paper plates.

Projection prints can be made on contact printing paper such as Kodak Azo Paper, Grade 3, from microfilm negatives in subdued room light and processed on the porous platen. The tungsten-illumination intensity where the paper is handled should not exceed 2 foot-candles, but the general room illumination can be much higher. This application is unique as it offers the possibility of obtaining quickly for short-term use positive reproductions from microfilms where darkrooms may not be available. A brighter lamp than the standard enlarger lamp is needed to reduce the printing time sufficiently so that the paper is not fogged by the room light during the exposure period. For example, by replacing the standard lamp in a Kodagraph Micro-File Enlarger, Model A, with a No. 1 Photoflood lamp, an exposure of 15 to 30 seconds at f/8 and 8× magnification will produce satisfactory copies from an average microfilm negative.

There are, undoubtedly, many other applications where the porous-platen processor may be a useful adjunct to the photographic process for a specific purpose.

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A NOVEL PHOTOGRAPHIC TECHNIQUE FOR PREPARING HALFTONE MASTERS FOR DIAZOTYPE REPRODUCTION

H. Carl How*

ABSTRACT

The technique of preparing a continuous tone photographic positive transparency for duplicating use in diazotype machines has been greatly improved by introducing a magenta halftone screen. The method assures at least three steps of additional contrast range and an increase in shadow area detail not possible in ordinary processing of transparent positives. The combining of line drawings and graphs with halftone subjects is accomplished with ease. A step by step laboratory procedure of exposure, printing, and development is described.

A NEED has long existed for a rapid and inexpensive method of reproducing continuous-tone photographic subjects in quantities less than one hundred copies. With text or line drawings, reproduction isn't much of a problem. Almost every office has a Mimeograph, a Multigraph, a Ditto machine, Ozalid equipment, or some other rapid and inexpensive *line* duplicating method. But the problem of reproducing *continuous-tone* art in small quantities usually poses the question: "Shall we use photographic prints or photo-offset printing?"

It has been estimated that approximately five hundred thousand reports are published in this country every year on technical subjects alone. It is probable that at least an equal number of administrative reports, business reports, accident insurance reports, and the like are also published annually. Most of these have quite limited distribution—perhaps twenty-five to fifty copies—and most of them include photographic illustrations. Therefore, the question of method must come up at least a million times each year.

Whether photographic prints or offset-printing is selected, as long as quantities of more than ten copies are involved and less than two hundred, the cost per reproduced page of the tone material is going to be ten, twenty or even fifty times as high as the cost per reproduced page of the line material. This means, of course, that the man preparing the report is going to think twice about using photographs or other tone material in his document.

The Diazotype Printing Process

There is a third alternative to the question of offset versus photographic printing. It is called diazotype printing—a rapid and inexpensive means of producing continuous-tone subjects on diazotype paper by means of a screened positive master (Figure 1). This method has the outstanding economic virtue of requiring only very moderate first cost and quite low unit costs per reproduced copy. In addition, it falls squarely within the domain of the photographer. Properly exploited, it could not only be of benefit in encouraging wider usage of photographic illustrations, but could also enable us to participate in a good share of the business of reproducing continuous-tone illustrations for the million or so limited-distribution publications turned out annually.

The idea of using diazotype prints to reproduce tone illustrations is not original, nor is it even very recent. However, like any new process, particularly in photography, it involves "tricks of the trade" that have to be learned the hard way. A number of photographers who have experimented with this process at one time or another, have run up against difficulties, and—probably more from the lack of sufficient motivation than for any technical reason—have abandoned the attempt.

The Central Photographic Laboratory of the Naval Ordnance Test Station was confronted with a backlog of several months orders for photographic prints, and this backlog was steadily growing. For a number of reasons, increasing the staff or subcontracting more than a fraction of the work was impossible. A new and rapid way to make prints had to be found. The diazotype printing method was resorted to in desperation and it solved the problem. The Los Angeles Police Department, faced with a similar problem, has gone through the same evolution and found in the diazotype print an answer to their problem.

The process has been developed to a practicable stage. At least two local photographic activities have used it successfully over a period of several years, and the "know-how" is now available to anyone in the photographic profession. Although a good many improvements still need to be made, the diazotype printing method even in its present stage offers such outstanding advantages and opportunities that every photographer should familiarize himself with it and adopt it as part of his stock in trade.

Preliminary Investigation

Initial experiments with continuous-tone subjects involved the making of positive transparencies without the use of a halftone screen. It was found that very soft gradation positives on film would reproduce to a moderate degree of quality. However, each negative was an individual problem, and usually required many test exposures. It was far from a production technique, and offered little more than confirmation that continuous-tone diazotype prints could be made.

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The first experiment with a screened halftone was performed by copying a printed halftone illustration from one of the trade journals. A positive of this was made using a high-contrast photomechanical film. Although detail and tonal gradation were lacking due to loss of dot structure, this positive reproduced much better than any of the previous continuous-tone positives. The result was sufficiently encouraging that a 133-line magenta contact halftone screen was procured to continue the investigations.

An intensive literary search was made to find information already available on this subject. In addition, other photographic laboratories and manufacturers of diazotype and photomechanical materials were questioned. The manufacturer of the magenta halftone screen could offer little real information. Attempts by others to screen positives apparently had met with little success and had been abandoned. The project would have been abandoned at this stage if any more promising method had appeared. Many pitfalls were encountered in the initial experiments with the halftone screen but, by trial and error, ways were found for avoiding most of them.

Fineness of the Screen

In the initial experiments, a 133-line magenta contact screen was used—a choice which subsequent investigations indicated is indeed the optimum screen. It can be assumed that a screen of the next finer gradation—150 lines—will resolve finer details. Whether or not it can be assumed that contrast control will be identical for all grades of screens, coarse and fine, can only be conjectured. The 133-line screen produces prints of such excellence that most lay observers never realize that the image they are seeing is screened. It is therefore recommended.

The film used to make the positive transparency must be photomechanical film of the same type used in photolithography and photoengraving, and for the same reason. The desired result is high contrast, with the halftone dots carrying the full burden of creating the illusion of intermediate tones.

Projection Screening

The simplest method for making the screened positive is by projection, and this should probably be the first method for anyone to attempt. This does not mean that contact methods are particularly difficult—it is just that a start must be made somewhere, and more people probably will have enlarging equipment than will have contact printers of suitable construction, or vacuum printing frames.

A condenser-type enlarger is the recommended equipment (Figure 2). The negative is placed in the holder with the emulsion toward the light source. This is the reverse of the procedure for making an ordinary photographic print. The reason for this is that the resulting transparency will read "right" through the back, and hence, during the later printing operation, the emulsion of the transparency will be in contact with the light-sensitive coating of the diazotype paper.

Focusing and composing are done in the usual manner on the enlarger base. In our operation we compose with an opaque mask backed up by white paper as a focusing aid.

Beneath the mask, which should be taped down to the enlarger base along one side, the photomechanical film should be placed with the emulsion side up. The magenta screen is laid on top of this, emulsion side down. On top of the whole assembly, a clean piece of quarter-inch plate glass is placed to assure fairly good contact of the materials.

Where the type of work permits, a printing frame can be used in place of the above arrangement. However it has been found that this simply added an extra complication with no particular advantage gained.

If the lens is stopped down to about f/11, exposures will be of the order of thirty seconds to one minute, depending, of course, on the density of the negative. All of the usual enlarging techniques, such as dodging, printing-in, and so forth, may be employed.

Development is carried on in the manner recommended by the manufacturer for the particular litho film being used. Usually two to two-and-one-half minutes are required at 68 F.

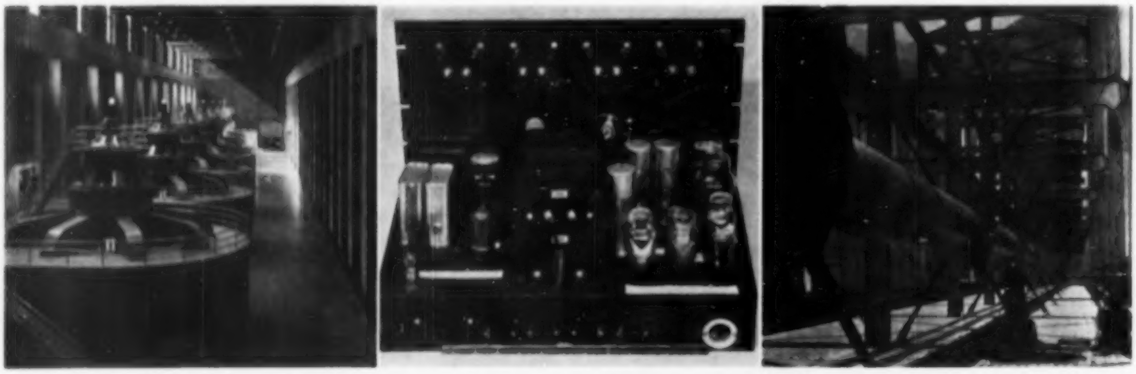

Fig. 1. Reproductions from diazotype prints made from 133-line screen positive transparencies. The reproduction is approximately 1/3 the original size.

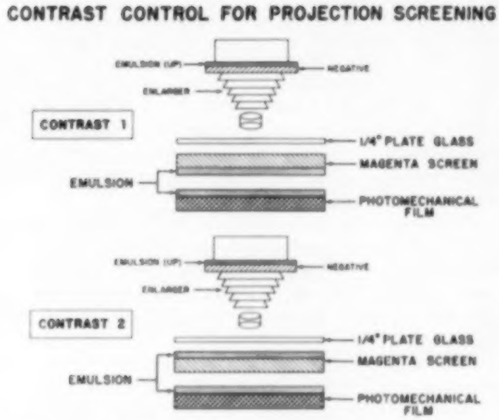

Fig. 2. Methods for controlling the contrast of halftone screened transparency films used for diazotype printing when projection printing is used.

After the transparency has cleared in the hypo, it should be inspected and evaluated. If it has the same shadow and highlight detail as a good lantern slide, it will produce a good diazotype print. If the contrast does not seem to be sufficient, increased contrast may be obtained in another exposure by simply turning over the screen so that its emulsion is towards the lens.

In contrast to the method of reproducing continuous-tone subjects, letterheads, captions, callouts, and all other line work should never be screened, but should be incorporated into the finished transparency by separately printing on a suitable contact printer. The operator should bear in mind, however, that the film is quite sensitive to light by comparison even to enlarging paper, and that exposures will therefore have to be short so that both elements of the exposed transparency will develop to the proper density in the same time.

Contact Screening

Having mastered the projection screening technique, the operator may wish to try his hand at contact screening. He will immediately discover that not just any contact printer will work. An analysis of the projection screening method reveals that the light source is collimated by the condensers of the enlarger and is reduced to a near point by the lens iris. With this clue, it becomes apparent that our contact printer must be of a type that provides, in effect, a point source of light producing a near-parallel beam.

If no suitable equipment is available or can be modified to meet this requirement, a printing frame can be used together with a small intense light source located five or more feet away. However, with this arrangement close contact between the elements in the printing frame will present a problem. The obvious answer—a vacuum frame—will be found not so obvious when tried, unless very low levels of vacuum can be maintained. Too much pressure between film, screen, and glass in the frame will give rise to Newton rings—which, of course, will show up in the end product.

In experiments at the Naval Ordnance Test Station, a Morse Aerial film contact printer was used. The only modification necessary was to change the light source from a 15-watt frosted lamp to a 100-watt, 20-volt double-coiled filament lamp. A 20-volt transformer and a Variac provided great control over exposures, both for screening halftones and for captions and other line matter requiring much less exposure. A frequent problem is to screen several negatives on one page by contact, as well as their captions, callout arrows, and running heads. Double printing in the usual manner on photographic paper, is, at best, difficult particularly when the negatives are of different gamma and density as frequently happens.

To screen by contact, the three elements necessary—that is, the negative, screen, and photomechanical film—are placed on the contact printer in that order (Figure 3). Normally, the negative is placed on the glass emulsion side down toward the light (contrary to photographic contact printing practice). Next, the screen is placed emulsion side up, and then the photomechanical film is placed emulsion side down. This is the order for effecting the lowest possible contrast.

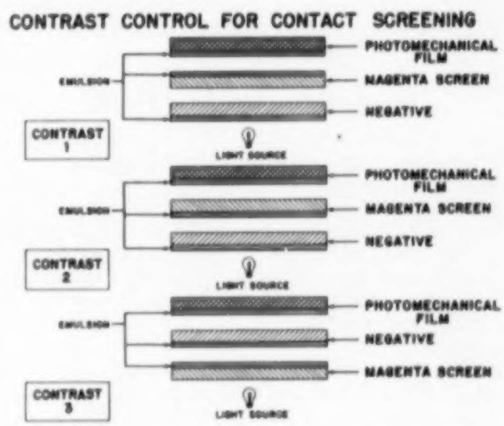

Fig. 3. Contact printing methods for controlling contrast of halftone screened transparency films for photographic production printing using diazotype material.

One grade of contrast greater can be achieved by turning the magenta screen over so that the emulsion side is down. To produce a third grade of contrast, the screen must change places with the negative, and the screen must then be turned back over so the emulsion is again face up. Exposures are of the order of 30 seconds at 20 volts for screened subjects, and 10 seconds at 10 volts for line work and captions.

When the final positive transparency has been produced, highlights can be pointed up and other retouching performed as necessary. All of the usual retouching techniques employed by photolithographers can be used here to advantage. The positive is then ready for printing.

Table 1

COMPARATIVE COSTS FOR MAKING 250 PRINTS FROM THE SAME NEGATIVE

	Photographic	Diazotype
Material		
Chemicals	$1.50	
Photomechanical film $8^1/_2 \times 11$ in.		$0.30
250 sheets $8^1/_2 \times 11$ in. paper	18.20	2.40
Total material	$19.70	$2.70
Labor		
Making 1 positive (10 min.)		.33
Making 250 prints (6 hrs.)	12.00	
Making 250 prints ($^1/_2$ hr.)		1.00
Total labor	$12.00	$1.33
Total labor and material	$31.70	$4.03
Production time required	6 hrs.	40 min.

Positive Printing

At this laboratory, printing is done on an Ozamatic high-speed printer, using Ozalid blackline standard, 105-S, paper. The Ozamatic is fast, easily installed, and semi-portable. However, other positive-printing diazotype equipment and printing materials may be used. In printing, since this is a positive-printing process, the transparency and printing paper are always placed emulsion to emulsion.

Comparative Printing Costs

With regard to comparative printing costs in terms of both time and money, the following is of prime interest. At this laboratory, an average $8^1/_2 \times 11$ inch screened positive takes about 10 minutes to make and costs about 65 cents for labor and materials (Table 1). To produce 250 prints takes about 30 minutes and costs $3.40 for labor and materials. Thus the total time to reproduce 250 copies is 40 minutes from start to finish, and the total cost is a little over four dollars, or less than two cents per copy.

Starting with the same negative and producing 250 photographic prints at this laboratory would take about six hours and would cost close to $32.00 for labor and materials, or about twelve or thirteen cents per copy.

Thus, for the run of 250 copies, the diazotype prints can be produced in about one-ninth the time and at about one-seventh the cost of the same number of photographic prints. These ratios, of course, will vary with the number of prints produced; however, diazotype printing will be cheaper than photographic printing for any number of prints greater than six.

It is not possible to make quite such a clear-cut comparison of diazotype printing with offset printing. This is because costs of offset printing vary quite widely according to the process, materials, and equipment used by different shops. However, for small quantities of the order of twenty-five to fifty copies, diazotype prints can be produced in only a fraction of the time and at much lower cost than any type of offset reproductions. In most cases, diazotype printing will retain its time and cost advantage over offset printing for quantities of one to two hundred copies.

Summary

Diazotype printing does not compete with photographic printing for very small quantities, nor with offset printing for large runs. Rather, it is to be regarded as a complementary process which fills a long-existing need that neither photography nor offset lithography has been able adequately to satisfy. This is the common need for a rapid and economical method of reproducing tone illustrations in quantities of ten to one hundred copies.

During the past three years this laboratory has screened thousands of negatives which had been exposed by a variety of photographers, both professional and amateur, under conditions ranging from optimum to impossible. In the course of meeting this constant challenge, a great many techniques have been worked out to meet specific problems. This process was found to be sufficiently flexible to achieve the desired end result in almost every case. It is recommended to the professional photographer as a practical, economical means of making successful continuous-tone reproductions.

THE RELATIVE PHOTOGRAPHIC EFFICIENCY OF CERTAIN LIGHT SOURCES

Robert N. Wolfe and Francis H. Milligan*

The *relative photographic efficiency* of a light source, when used with a certain photographic material, can be defined as a number by which the measured illuminance of a nonselective reflecting surface on which the light is incident must be multiplied to obtain the illuminance from a reference source that would produce the same photographic response in the same time.

Values of relative photographic efficiency for a number of light sources are shown in the table. The reference source used is the primary photographic standard.

Efficiency values are given for three different sensitizing types (non-color-sensitized, orthochromatic, and panchromatic).

* Research Laboratories, Eastman Kodak Company, Rochester 4, New York. Excerpted by the authors from Communication No. 1545 from the Kodak Research Laboratories and reprinted from The Journal of the Optical Society of America, Vol. 43, pp. 791–797, September 1953. Received 1 December 1953.

Because of the variation of sensitizings for different photographic materials and the manufacturing variations of lamps, it should not be assumed that these specific values of photographic efficiency will apply to any particular combination of light source and photographic material. These data should, rather, serve as a guide to indicate differences to be expected between various combinations of sources and photographic materials.

RELATIVE PHOTOGRAPHIC EFFICIENCY OF CERTAIN LIGHT SOURCES

Light Source		Color temperature, °K	Relative photographic efficiency for various sensitizings: Non-color-sensitized	Ortho-chromatic	Pan-chromatic
Primary photographic standard†			1.00	1.00	1.00
Washington mean noon sunlight (calculated)			1.20	1.10	1.05
Rochester 60° sun			1.65	1.05	1.15
Zenith blue sky			7.00	2.85	3.00
Zenith overcast sky			2.10	1.50	1.30
Tungsten		1896	0.08	0.29	0.52
Tungsten		1996	0.10	0.30	0.52
Tungsten		2095	0.11	0.31	0.54
Tungsten		2194	0.14	0.36	0.54
Tungsten		2353	0.21	0.42	0.58
Tungsten		2491	0.26	0.46	0.60
Tungsten		2650	0.31	0.51	0.63
Tungsten		2738	0.33	0.52	0.64
Tungsten	CIE Illuminant A	2835	0.40	0.55	0.66
Tungsten		2985	0.45	0.57	0.68
Tungsten		3182	0.53	0.61	0.69
Tungsten		3365	0.65	0.73	0.78
Tungsten		3448	0.69	0.76	0.79
2650 K tungsten + D-G filter		3085	0.45	0.60	0.70
2835 K tungsten + D-G filter		4000	0.80	0.85	0.85
2835 K tungsten + D-G filter	CIE Illuminant B		0.90	0.95	1.00
2835 K tungsten + D-G filter	CIE Illuminant C		1.45	1.35	1.25
Photo Blue, 250-watt			0.90	1.05	0.95
Photo Blue, 500-watt			1.25	1.20	1.05
No. 1 Photoflood, blue bulb			0.95	0.90	0.85
No. 2 Photoflood, blue bulb			0.70	0.95	0.75
No. 4 Photoflood, blue bulb			0.95	0.90	1.05
Fluorescent, blue white, 40-watt (RF)			1.95	1.75	1.50
Fluorescent, daylight (6500), 40-watt			1.25	1.50	1.20
Fluorescent, white (3500), 40-watt			0.70	0.70	0.75
Fluorescent, blue, 40-watt			5.10	3.25	3.00
Fluorescent, green, 40-watt			0.30	0.55	0.50
Fluorescent, pink, 40-watt			0.70	0.55	0.75
Fluorescent, gold, 40-watt			0.01	0.20	0.45
Fluorescent, red, 40-watt			0.01	0.01	0.60
	Vapor pressure				
Mercury, 260-watt Cooper-Hewitt (50")	0.0003 atm		3.30	2.55	1.75
Mercury, 400-watt H-1	1.0		1.35	1.15	0.90
Mercury, 100-watt H-4	8.0		2.25	1.75	1.40
Mercury, 100-watt S-4	8.0		3.15	2.05	1.50
Mercury, 1000-watt H-6	75		3.40	2.45	1.60
Argon, 2 1/2-watt			200.0	60.0	40.0

† 2353 K tungsten + Davis-Gibson filter. See American Standard Z38.2.1-1947.

PROBLEMS IN THE DESIGN OF AN 8MM MAGNETIC SOUND-ON-FILM PROJECTOR

Lloyd Thompson*

Users of 8mm motion picture equipment have long wanted an 8mm sound-on-film projector. Optical type 8mm sound reproducers have proved impractical. The magnetic type of machine seemed to be more promising, for several reasons. With a magnetic sound-on-film projector the user can record his own sound as well as play it back, and this seemed to be a highly desirable feature for amateur film users. Also old silent films can be given a sound accompaniment after a magnetic track has been applied to the film. Magnetic tracks on 8mm films, however, impose their own problems in sound projector design. The 8mm film runs at a slower linear speed than does 16mm or 35mm film. Even when projected at 24 frames per second its speed is only 18 ft per minute. It was considered necessary to design a projector which would satisfactorily record and play back both at the slower silent film speed and at the current sound film speed. Such equipment would interest owners of old film who, by having a magnetic sound track striped on them, could add sound to the old films. The two-speed requirement complicated the design problem.

Another source of trouble was in guiding the film. Since the magnetic sound track is placed outside the sprocket holes on the margin of the film it can be no wider than approximately .025 of an inch. The film must be guided accurately so that the magnetic track will always line up over the record and playback head in the same position. The sound head could not be made wide, extending on both sides of the striping, because some of the magnetic coating might run over into the sprocket holes during application. This would introduce a great deal of sprocket "flutter" if a wide recording and playback head was used. Therefore, the recording and playback head was restricted 0.025 inch.

The narrow track and correspondingly narrow recording and playback head require accurate guiding of the film and accommodation for different widths. Because 8mm film is exposed in the camera as 16 mm film and slit in half after processing, the accuracy of slitting is not always maintained as it is in the film factory where the unexposed film was produced. Because of slitting inaccuracies and because of shrinkage, 8mm film is not always 8mm wide. A guide system to work satisfactorily has to take this fact into consideration.

Good results in magnetic recording, whether it be on film or tape, demands that the magnetic coating be in good contact with the recording and playback head. Film is rather stiff compared to cellophane tape, which is used for magnetic recording on most 1/4" magnetic tape recorders. For that reason, it is a little more difficult to keep film in good contact with the head. Also different rolls of film will have different amounts of curl in them, so that a contact device must maintain contact even though there is a varying amount of curl in the film itself. Of course, if the film is damaged or there is too much curl in it, it may be impossible to get contact, but such films are in the minority.

The problem of flutter is very bad in 8mm film because the magnetic striping is placed along the outside edge of the sprocket holes. When the sprocket holes are punched in the film, there is naturally a deformation of the film at that point. If the usual method of putting the film around the sound drum is used on an 8mm magnetic film projector, sprocket hole flutter will be introduced in the recording and playback mechanism. A

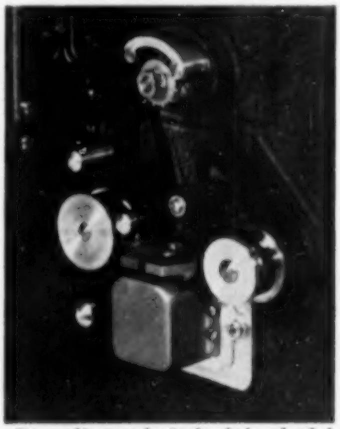

Fig. 1. Recording and playback head of the Movie-Sound 8mm projector showing the Roto-Magnetic Stabilizer.

sound system has been developed to overcome the difficulties just mentioned. This system, described in a pending U. S. Patent, is called the Roto-Magnetic Stabilizer. It utilizes a principle which is called a combination of tight loop and loose loop system.

The loose loop system, used on early 16mm sound projectors and some modern ones, is capable of excellent sound results. One disadvantage of such a system, however, is a tendency to produce "wows" in the mechanism or in and out of focus with the light beam if the film has excessive curl. This difficulty was largely overcome by changing to what is known as the tight loop system that is widely used on sound projectors today. For 35mm and 16mm films the tight loop system seems to work quite satisfactorily, but when it is tried with 8mm film it gives difficulty. It has a tendency to damage the sprocket holes rather easily and, because of the closeness of the sprocket holes, it makes such a machine rather difficult to design so that it can be threaded properly.

* The Calvin Company, Kansas City, Missouri. Adapted from a Motion Picture Division talk presented at the PSA National Convention in New York, New York, 12 to 16 August 1952.

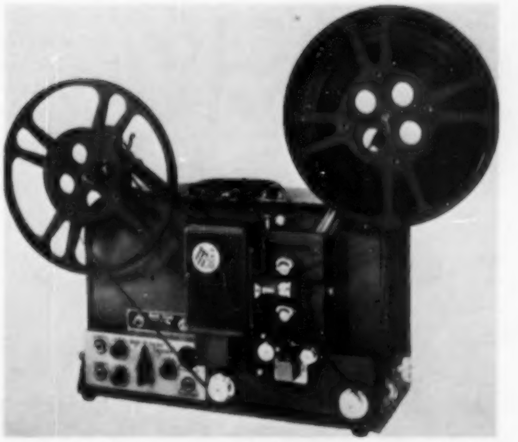

Fig. 2. The 8mm sound film projector ready for operation. The demountable reel arms fit in the cover of the case, which also contains the speaker and the microphone, so that only one case is needed to transport or store the entire unit.

The dual flywheel system of recording and playback is a tight loop system that gives very good results with 35mm and 16mm films but when used with 8mm film it seems to have certain disadvantages

For those reasons, the Roto-Magnetic Stabilizer was designed to use the tight loop system only on the take-up side of the record and playback head. Between the intermittent and the record playback head the loose loop system is used. Such a system makes the projector easy to thread, it is easy on the film being handled, and it is comparatively simple to build. As shown in Figure 1, two drums are used as in the double flywheel arrangement. However, on the Roto-Magnetic Stabilizer the double flywheels are used in a different manner. On the drum next to the take-up sprocket is mounted a rather large flywheel which floats on the shaft. It was necessary to use this rather large flywheel in order to get good film motion at the slow speed at which 8mm travels. It floats on the shaft to avoid injuring the film when the mechanism first starts. On the back of the other drum is a rather small flywheel. This tends to hold the film tight between the two drums as it goes over the record and playback heads.

The drum containing the large flywheel has been made with an edge guide and has been tapered slightly in manufacture so that the film has a tendency to run to the outside edge and against the guide on the edge of the drum. This means that the outside edge of the film containing the sound stripe is always in line with the record and playback head and this is done automatically whether the 8mm film has been slit oversize or undersize.

The other sound drum is covered with a rubber tire which has a tendency to grip the film so that the film is always held back at a uniform tension as it passes over the record and playback head. The intermittent motion is filtered out just before the film reaches this drum so that by the time it reaches the record and playback head there is no trace of the intermittent motion left in the film. Contact on the record and playback head and on the erase head is maintained with small rollers.

In building an 8mm sound-on-film projector, it was impossible to adopt very much of the conventional 8mm silent projector design. For example, most silent projectors have a universal type of motor with a brush type commutator. Such a motor can be quite small and it also can be placed quite close to the rest of the operating mechanism on the projector. In an 8mm sound projector, it is impossible to do this because there is so much noise created by a brush type motor or a governor type motor. It is much simpler to use a motor without brushes than it is to try to get the noise out. Even so, the motor is likely to cause electrical disturbances and for that reason it is a good idea to get the motor as far away from the recording head as possible. A Bodine constant speed motor was selected and placed on the back of the machine as far away as possible from the sound head. Conventional projectors have always used high speed motors because they are cheaper and also because the higher speed gave them more air for cooling purposes, which was needed with large lamps. While high speed motors are satisfactory from this standpoint, they are more noisy than slow speed motors and a high speed fan is rather noisy in operation. A slow speed motor was selected, therefore, and a slow speed fan to deliver a volume of air to cool lamps up to 750 watts, without noise from either the motor or the fan. In storing the projector, the reel arms are taken from the machine and placed in the lid of the case, which also contains the speaker and microphone, so that the whole unit fits into one case. Figure 2. The weight of the machine is approximately 35 pounds.

The machine comes with a two channel amplifier for recording purposes. It is possible, therefore, to record from a microphone and from another source of sound such as a turntable at the same time. The two signal sources can be mixed together so that there is background music or sound effects behind voice, and the level of the voice and the music are independently controlled. A headphone jack is provided so that the mix can be monitored at the time of recording. A separate mixer with several channels is available as an accessory.

The volume is indicated by a small neon lamp, Figure 3. An erase head has been built into the record and playback head so that any old signal is automatically erased just before the new signal is recorded, when the

Fig. 3. Control panel of the 8mm sound film projector.

amplifier is in record position. A mechanical safety lock is built into the control switch so that it is not possible to accidentally erase previously recorded sound.

In order to record sound-on-film, it is only necessary to place a magnetically striped film in the projector and put the control switch on record position, adjust the volume for recording, and proceed to record. After the recording is done, the film is rewound, it is rethreaded into the projector and projects a sound picture. If, for any reason, the recording is not satisfactory, a new recording can be immediately made and the old track will be erased as the new one is being recorded.

TIME-LAPSE CAMERAS AND THEIR INDUSTRIAL USES

John R. Huffman*

Micro-motion pictures are utilized by industrial engineers to record and to time human motions performed too rapidly for on the spot, visual evaluation. Such 16mm pictures, taken at 1,000 to 4,000 frames per minute, can be analyzed to establish more effective motion patterns that will permit increased output without additional worker effort. When operations requiring as little as 5 or 10 seconds to perform are repeated many times, the motion pattern improvements obtained by this technique can save thousands of dollars per year.

Frequently the industrial engineer desires to isolate noticeable idle periods, delays, and methods variations in operations requiring longer periods of time or irregular sequences of elements. Normally these tasks would be time studied, but the problems of isolating and recording short delays, idle periods, etc. scattered within the cycle make this difficult. When the work is carried out by a crew of men, obtaining such data becomes a much greater problem, even if the activities of each worker are recorded by a different time study man.

Realizing that moving pictures would record such operations for later analysis and also realizing that normal motion picture rates of 16 frames per second were unnecessary, Dr. M. E. Mundel developed a 16mm, synchronous motor-powered camera which could expose one frame of conventional motion picture film every .01 minute. The .01 minute interval was selected because stop watches used for time study usually are read to the nearest 0.01 minute. This was the first "time lapse" or "memo-motion" camera.[1]

Typical Time-Lapse Cameras

Two time-lapse cameras have been designed and fabricated at the University of Southern California. The earlier model, shown in Figure 1, consists of a Victor Model 3 camera, the spring motor of which was replaced by a surplus $^1/_{300}$ horsepower synchronous motor and gear box. Since this unit operates at 100 frames per minute ($^1/_{30}$ of a second exposure) only, it will record 45 minutes of continuous action on 100 feet of film.

Figure 2 shows a later camera made by modifying a GSAP wing gun-camera in accordance with the author's design. The original motor shown in Figure 3 was replaced by the simple gear train and $^1/_{1500}$ horsepower, 110 v. synchronous motor seen in the picture. The old shutter (not shown) was replaced by a 24° opening one (made more visible in the picture by the piece of paper inserted behind it). The C-mount, tripod mounting bracket, 110 v. switch, and wiring seen in Figure 2 are common modifications of the GSAP.

When this camera operates at 100 frames per minute ($^1/_{25}$ of a second exposure), it will record 25 minutes of an operation on its 50-foot magazine of film. Speed changes to 50 and 200 frames per minute—with corresponding increases and decreases in exposure and running time—are effected by the speed selector unit already in the camera.

Research Applications

Especially within the past five or six years industry has become interested in materials handling, and the

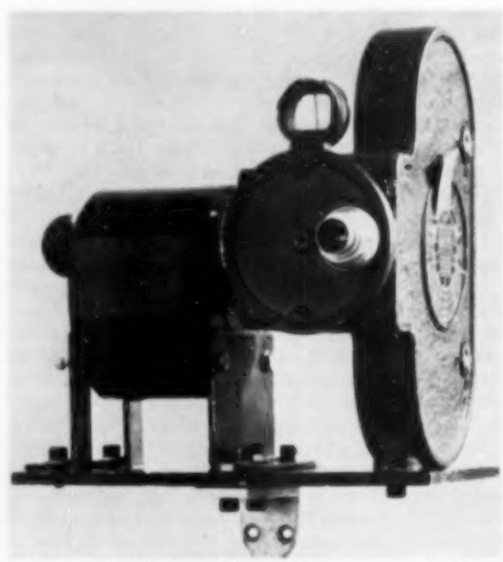

Fig. 1. First USC time-lapse camera constructed from Victor 16mm camera, operating at 100 frames per minute.

* Department of Industrial Engineering, University of Southern California, 3518 University Avenue, Los Angeles 7, California. Received 27 November 1953.

Fig. 2. GSAP 16mm magazine film camera adapted for time-lapse photography. The speed selector already incorporated in the camera provides speeds of 50, 100, or 200 frames per minute.

job-lot nature of most manufacturing plants has focused much of this interest on mobile handling equipment such as the fork lift truck. Operations utilizing such equipment generally require one-half minute or more; they include many short delays because the truck slows down or stops at a cross aisle, to avoid a worker, or to let another truck maneuver; the time required to perform a given task depends upon the skill of the operator. In short, materials handling operations have characteristics that are made to order for time-lapse camera analysis.

The Industrial Engineering Department at the University of Southern California has used the camera shown in Figure 1 for research into the effect of aisle widths and individual differences on the time required to perform the elements of the typical fork lift truck handling operation shown in Figure 4. Since the truck had to be coasting, braking, lifting and tilting, or moving in one of four speeds at any time, each activity was indicated by one combination of the lights attached to the truck and visible in Figure 5. The aisle width and distances along the aisle were marked with special tape that also can be seen in that figure. The camera, then, recorded on film (at intervals of .01 minute) the motions of the operator, the location of the truck and its activity—coasting, braking, etc.

The value of the time-lapse camera was evident when two of the operators consistently required 8 to 10 and 12 to 15 frames respectively to perform one portion of the operation while the third performed it eight times in 11 to 14 frames and twice in 17 frames. Had stopwatch timing been used, these last two values would have been suspected because it is possible to misread .12 minutes as .17. Reference to the time-lapse film showed that the two 17-frame values were the result of hesitations and uncertainties on the part of the operator.

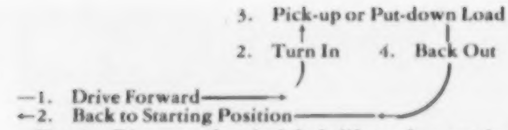

Fig. 4. Diagram of typical fork lift truck operation investigated by use of time-lapse cameras.

These resulted in alternate periods of coasting, power application, and braking which did not occur in the 11- to 14-frame cycles. A similar analysis of interindividual differences showed that the most skillful operator braked more rapidly, coasted little or none, and generally operated the truck at higher speeds than the least skillful.

When it became desirable to add the time required to accelerate and decelerate the truck to element times based on operator motions, the film was available; a little analysis yielded the desired information. Inability to reanalyze time study data in this fashion is hampering the comparison of stopwatch data taken by other research people.

Other research[2] conducted by Prof. W. J. Richardson of Lehigh University has utilized a time-lapse camera to record the times required, the paths employed, and the delays encountered by fork lift trucks operating in one department of a medium sized metal working plant. From the film record he developed an equation which predicts the time required for a truck to travel a given distance with a specified number of aisles to cross, etc.

Other Time-Lapse Camera Uses

To the best of the author's knowledge crew activities have been recorded for analysis by the memo-motion camera in companies all over the country.[3] This has been going on for a number of years and will undoubtedly continue.

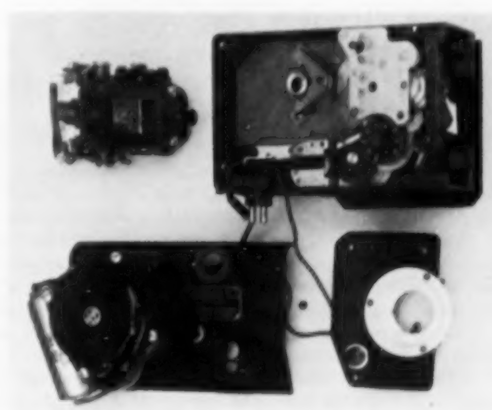

Fig. 3. Details of conversion of GSAP camera (Fig. 2) to time-lapse photography. Original motor, upper left, has been replaced by new synchronous motor shown mounted on the camera cover in lower left. A new gear train has been installed. A new shutter with 24° opening is shown with white paper inserted behind it for visibility in the illustration. Lens mount, tripod-mounting bracket, 110 v switch, and new wiring have been added.

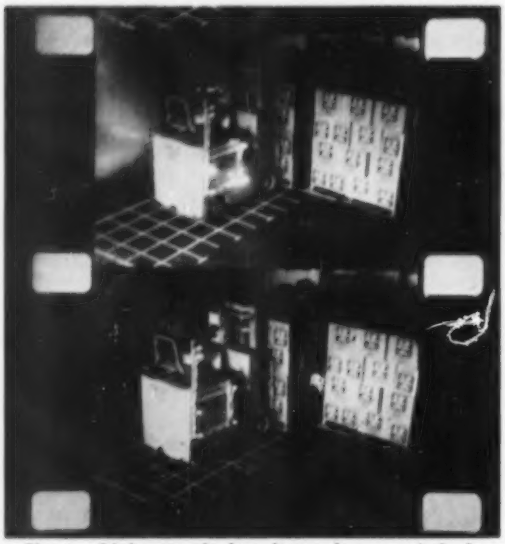

Fig. 5. Lights attached to the trucks are switched on and off in different combinations during coasting, braking, lifting, and tilting, or moving in one of four speeds, to indicate what is taking place at the time the sequence pictures are recorded on 16 mm film at intervals of 0.1 minute.

A slightly different, and perhaps prophetic, time-lapse camera application has been reported by the Bell and Howell Company.[4] Faced with traffic congestion at an elevator, that company's Industrial Engineering Department decided to ascertain the nature and magnitude of the problem by sampling. Their sampling device was a 16mm motion picture camera with an interval timer. Their sample consisted of time-lapse exposures taken automatically at intervals of eight seconds. Since a 100-foot roll of film was sufficient to record activities for a period of eight hours, the data needed to solve the problem were obtained very economically. Some statistical analysis suggested an appropriate answer to the problem; the application will suggest many others to any industrial engineer.

The increased use of the time-lapse camera has resulted from industry's growing effort to establish facts about materials handling operations. Since materials handling is commonly considered the one remaining industrial cost that can be reduced substantially, there is every reason to believe the time-lapse camera will find increasing use in such studies. Investigators who use photography to analyze material handling operations will discover its possibilities as a sampling device and find even more interesting applications for this industrial engineering tool.

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AN APPARATUS FOR 3-D CINE-PHOTOMICROGRAPHY

Zane H. Price*

The improvement of the optical microscope since its invention some 350 years ago has been evidenced in two directions. First has come the refinement of the instrument through changes in design for greater comfort and efficiency, improved adjustments, better optical accessories, and more effective methods of illumination and of resolution. The second phase of improvement recognizes the optical properties of the object under scrutiny and considers it as an essential part of the optical system. Such efforts have resulted in the development of the darkfield, the fluorescent, the infrared, and the phase microscopes.

Regardless of the type of microscope, other than the low powered Greenough, the object is observed in two dimensions only and the observer must resort to constant fine focusing and his imaginative experience to create an idea of a third dimension.

Stereomicrographs obtained with a compound microscope became possible with the advent of photography. The object is tilted on the stage of the microscope at approximately 7° and one exposure made, after which it is tilted to the same degree in the opposite direction and the second exposure made. The 16 mm lens is usually the shortest practical focal length objective for use with this method. Higher magnifications do not provide enough depth of field, and the half-condenser aperture method must be employed. This technique requires opposite halves of the condenser annulus covered with an opaque material for each successive exposure. Both methods involve photographic representation and are confined to still objects.

The advent of polarizing sheet material made possible both visual and photographic microscopy of moving as well as still objects. 3-D visual microscopy with the

* Department of Infectious Diseases, School of Medicine, University of California at Los Angeles.

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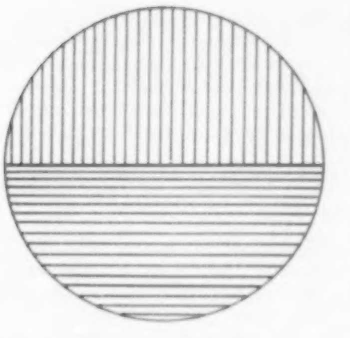

Fig. 1. Schematic diagram of field splitting polarizer illustrating perpendicular planes of polarization.

shorter focal length objectives is accomplished through the use of a binocular, mono-objective microscope. In the condenser annulus of the microscope is placed a disc of polarizing sheet material consisting of halves in which the lines of polarization are at right angles (Figure 1). Thus, the light reaching each ocular vibrates in a different plane. By placing polarizing sheet material above each ocular in such a manner that the plane of polarization corresponds to that of one half of the condenser annulus, two separate beams of light emerge from the microscope. Inasmuch as the two beams of light come from opposite sides of the specimen, a stereo image is seen. Stereoscopic microscopy with the compound microscope is now an accepted laboratory practice. Three - dimensional cine - photomicrography thus becomes a possibility. The purpose of this paper is to present a method of operating the motion picture cameras in synchronization.

The Microscope

Any standard binocular, mono-objective microscope may be used provided it has a filter ring attached to the condenser to hold the split field polarizer. If much work is to be done with the 16mm objective, the top element of the condenser should be detachable.

The Polaroid Filters

Three dimensional effects with the microscope are obtained by the use of a set of standard Polaroid filters supplied by Bausch and Lomb Optical Co. (Figure 2). The set consists of two ocular caps and one split polarizing filter with an orientation arm attached. One half polarizes in a direction parallel to the handle; the other half at right angles to the handle. The polarizer must be inserted in the ring below the substages with the handle pointing directly away from the observer. This splits the field vertically.

Fig. 2. Stereo polarizers arranged in respective positions for use on a binocular microscope.

One of the caps is set on the right ocular with the white line on its rim oriented vertically, the other cap is set on the left ocular with its white line horizontal. The microscope is now ready for stereo observation or photography.

Light Source

A high intensity light source is essential because of the absorption of the Polaroid filters, and the beam splitters attached to the cameras. A 500- to 1000-watt biplane filament T-10 projection lamp usually will provide adequate illumination, but it may be necessary to resort to an arc lamp at times, particularly with color materials or the phase microscope. The lamp is adjusted for standard Koehler illumination.

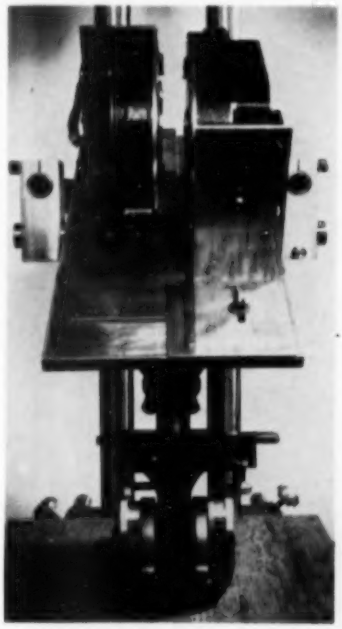

Fig. 3. Two Bolex 16 mm cameras mounted back to back on camera carrier for stereo cine-photomicrography.

Cameras

Any 16mm or 35mm motion picture camera may be used providing the design of the camera permits placing the film aperture of each camera over the respective oculars of the microscope. Because most binocular microscopes have an ocular separation of not more than three and one half inches, the cameras must be placed close together. The H-16 Bolex has been found satisfactory if the two cameras are placed back to back (Figure 3). This of course means that one film must be reversed for projection.

The Beam Splitter

Some method of aligning and focusing the two cameras is mandatory. The beam splitter has been found satisfactory for this purpose. It can be obtained from a commercial source or it can be homemade. Needless to say, it must be precisely machined so that it insures accurate alignment between microscope and camera and it must pass adequate light through the side telescope for visual focussing. The beam splitters which use a ground glass to register the image do not, as a rule, furnish a sufficiently defined image.

The Optical Bench

Proper alignment of each element of the system must be provided for, and the relatively inexpensive Shop Smith has been found to be ideal. The Shop Smith is a utility wood working machine that is rigid, precise, and readily obtainable. The parts essential for mounting the equipment can be ordered from the factory or from a distributor by part numbers (Figure 4).

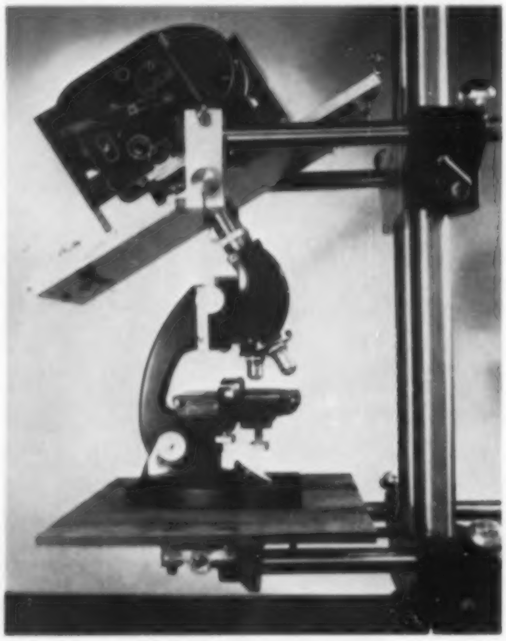

Fig. 4. Camera carrier and microscope mounted on optical bench improvised from Shopmaster woodworking equipment. The synchronous motor drive and the beam splitters have been removed.

When each element of the system is mounted on the Shop Smith carriages and properly aligned, a very efficient cine-photomicrographic unit results.

Camera Carriage and Synchronization

The camera carriage insures a method of holding and aligning the two cameras over the oculars of the microscope. The design worked out for this unit was relatively simple and easy to construct. It provides 5-way adjustment for each camera; east, west, north, and south and movement away from vertical to compensate for oculars which are tilted to the left and the right on some makes of microscopes. The whole mechanism can be set at an angle to the horizontal to allow for oculars that are inclined toward the microscopist.

Synchronization of the two cameras, vital to two film 3-D motion pictures, is obtained by a single shaft which has two sprocket gears mounted on it. The whole in turn is fitted to the camera carrier. The sprocket gears are movable on the shaft to provide for displacement of the cameras. The sprocket gears have Allen screws to lock them once they are aligned with the camera. The cameras have a similar sprocket fitted to their drive shafts and it is connected to the universal shaft sprocket by a small sprocket chain. The chain allows the two cameras to be tilted right or left from the vertical. The whole drive unit is operated by a suitable synchronous motor to run the cameras in phase.

Conclusion

Acceptable three dimensional cine-photomicrographs can be made with the binocular, mono-objective microscope equipped with a Bausch and Lomb stereo polarizing set. The apparatus for holding the two cameras above the oculars of the microscope and running them in phase need not be elaborate, but means must be provided for aligning the cameras and focusing each one. The construction of such an apparatus is described.

The routine techniques of microscopy are no different except for the use of high intensity light sources to overcome light absorption by the complex optical system.

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SENSITOMETRIC CONTROL FOR CONTINUOUS PROCESSING MACHINES

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ABSTRACT

The conversion from batch to continuous methods of processing and printing aerial roll film created new problems in printing and processing control. To obtain prints and negatives of optimum quality called for a simplified method of sensitometric control suitable for field use. Light, rugged, and air-portable sensitometric equipment has been designed. A visual method for obtaining sensitometric data directly from the sensitometric strip was derived. The design of this equipment and its application to photographic processing, printing, negative duplicating and solution replenishment are discussed.

SINCE THE BEGINNING of World War II, a revolution in printing and processing methods has occurred within the Air Force. The demands by modern reconnaisance photographers for more and better prints in less time has resulted in a program for conversion from batch type to continuous methods of printing and processing. The Photo Reconnaissance Laboratory, Directorate of Laboratories, Wright Air Development Center, is the activity engaged in the development of this continuous processing and printing equipment.

To achieve consistently high quality negatives and prints, better control of processing solutions and printing operations was necessary. As early as 1943 preliminary studies of the required characteristics of negatives and prints were made to determine the minimum amount of control required. The sensitometric control system which has been developed meets these minimum requirements and is simple enough to be handled successfully by the relatively untrained technicians in the field. This paper discusses the design of equipment and its application to processing solutions control and to negative duplicating and printing processes.

Design of Equipment

The system of sensitometric control is intended for all continuous processing and printing operations, whether they are located in small mobile laboratories or permanent installations. The size and weight of the equipment, therefore, are of paramount importance. To meet Air Force requirements the equipment must not only be small and rigid enough to withstand rough handling, but must also be resistant to fungus, to high and low temperature storage conditions and to corrosive atmospheres, such as salt sea air. Commercial sensitometric equipment does not meet these requirements, consequently three pieces of equipment were developed, i.e. a sensitometer, a processing sink and a densitometer.

The AF Process Control Sensitometer is an intensity scale instrument which is much more compact and lighter in weight than commercial models. It is 10" long, 8" deep and 16" high and weighs less than 30 lbs. Many of the essential parts and the general overall design are shown in Figure 1. The light source is a General Electric 50-watt toy projector lamp, the intensity of which can be controlled through a variable resistance and a voltmeter. Since power supply systems encountered in the field are subject to excessive voltage fluctuation, a voltage stabilizing transformer has been incorporated as an integral part of the sensitometer. The duration of the exposure is adjustable by seconds from 0 to 30 seconds by means of an electrical timer and a solenoid-operated shutter. Tests conducted at the Photo Reconnaissance Laboratory indicate an accuracy

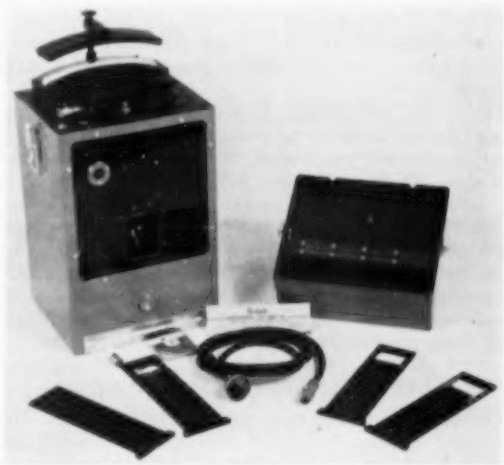

Fig. 1. Process control intensity scale sensitometer designed by U. S. Department of the Air Force for use in controlling continuous processing of photographic films and papers.

of exposure time at 4 seconds of approximately $^1/_2$ of one percent. As the lamp is located relatively close to the exposure plane, the platen has been slightly curved to improve the uniformity of illumination. The sensitometer uses an Eastman No. 2 square-root-of-two photographic film wedge with 5 mm steps. For paper sensitometry it was decided that a wedge with smaller density increments would be desirable. The square-root-of-two wedge was converted to a fourth-root-of-two wedge by preparing an over-lay, one half of which has been exposed and developed to a density of 0.075 above base. This overlay is fastened to the wedge when exposures are made on photographic papers. Since this

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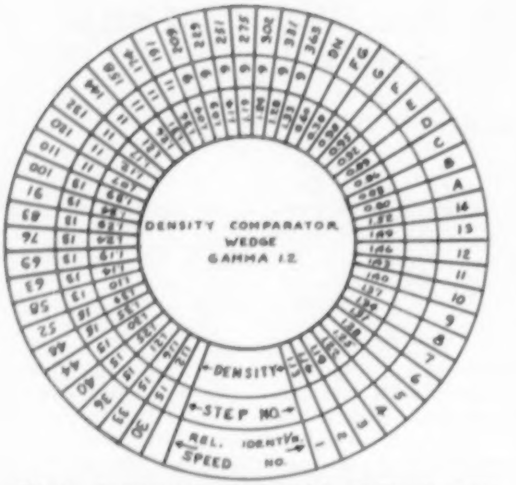

Fig. 2. Comparator wedge used in AF Densitometer to estimate "speed" and gamma values from sensitometric strips. An accuracy of ±0.10 gamma is claimed.

sensitometer was designed for use with both high-speed films and enlarging papers, suitable color correction and neutral-density filters have been provided, so that no change in the lamp is required for materials of widely different speed.

The second component, a small sensitometric developing sink, is designed to process two 16mm by $7\frac{1}{2}$" sensitometric strips simultaneously but in separate tanks. It is about 18 in. square and 36 in. high when completely packed for shipment. The rate of agitation is adjustable so that developments can be made to correspond to those obtained in the continuous processing machine. Temperature control from 65 to 90 Fahrenheit with a control accuracy of $\frac{1}{2}$° has been provided. Suitable timers have been incorporated to time the processing cycle for both film and paper.

The Small, Portable Densitometer

The final piece of equipment is a small, portable densitometer. Although several commercial models were available which would meet the AF requirements for size and weight, it was felt that from an operating stand-point a densitometer which would read sensitivity and gamma directly would be desirable. Such an instrument would reduce the training problems and would minimize the resistance of operating personnel to sensitometric control methods.

Early attempts to construct a direct reading densitometer were made by comparing the sensitometric strip directly against certain standard densities. This approach was found to be feasible. However, the difficulties encountered in matching strips of different image color and grain structure interfered with the accuracy and reproducibility of the method. It was decided that, if a "field within a field" type densitometer such as the "Capstaff-Purdy" were utilized, better results would be obtained. Subsequently the wedge on an Eastman Color Densitometer Model 1 was modified and the functional difficulties of this method were corrected. The AF densitometer currently being developed will be compact and will operate either from batteries or 110 v alternating current.

So far the basic design of the densitometer has been discussed but the method of computing the wedge densities required for the direct reading of contrast and speed has not yet been covered. The method for their derivation will be amplified in the succeeding paragraphs.

In this densitometer the measurement of gamma depends on measuring the difference between two different steps on the sensitometric strip. This method of determining gamma has been suggested by Neblette[1] and others, however the manner in which it is carried out is perhaps somewhat unique. Figure 2 is a schematic drawing of the comparator wedge showing the densities and their identification. The densities lettered A through G start at 0.80 and increase in increments of 0.03. The numbered densities 1 through 14 start at 1.13 and also increase by 0.03 increments. To measure the gamma, the operator simply matches one of the lettered densities A through G with the appropriate density on the sensitometric strip. He then moves the strip two steps in the direction of greater density (for example from step 9 to 11) and matches the density with one of the numbered densities (1 through 14). The gamma is then read directly from a scale located on the body of the densitometer opposite the letter of the A through G series previously selected. Our tests indicate that the visually determined gamma will be within ±0.10 gamma units. This is believed to be sufficiently accurate for the intended AAF application.

The measurement of sensitivity of the photographic material is predicted on the assumption that over a limited range of gammas, the sensitivity of the material can be determined as a function of density. Since the gamma produced by the AF developers normally does not change appreciably over the normal use period of the developers, this method has been found satisfactory for process control. The sensitivities and their associated densities on the comparator wedge, shown in Figure 2, are derived from one set of curves which vary by a Log Exposure difference of 0.04 and have identical gamma, namely 1.2. If such a set of curves are drawn, as in Figure 3, the difference in speed between curves A, B, C, D, E, is shown as a difference in density for any specific step on the sensitometric strip. For example, assume that Step 11 has a relative sensitivity of 144 and a density of 1.2 (curve A), then a sensitivity of 158 (curve B) is represented by a density of 1.26. In like manner the densities and sensitivities for curves C, D, E, etc. can be determined. Experiments have shown that this method will function satisfactorily if the test gamma is not more than ±0.2 gamma units from the gamma used in calculating the wedge.

It is recognized that if the average process gamma is very much above 1.4 or below 1.0, confusion may result; since with high gamma it may be difficult to attain a satisfactory match between the wedge and the sensitometric strip, while at gamma below 1.0 there will be two different sensitivity points for the same strip. For this reason three wedges calculated for average gammas of 0.90, 1.2 and 1.5 will be supplied for this densitometer. Because the brightness range of aerial subjects is con-

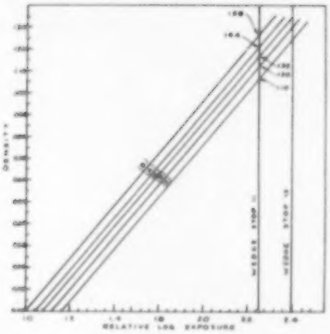

Fig. 3. Control chart for estimating sensitivity of films from AF sensitometric strips. The parallel lines are drawn at 1.2 gamma and are separated by intervals representing log exposure differences of 0.04.

siderably less than for ground photographs, higher gammas are required for aerial film to effect adequate separation of subject detail. It is believed however that these three wedges will cover satisfactorily the range of gammas normally encountered. Since the process average for any particular combination of processing machine, film, and developer will fall within the range of one of the comparator wedges, it is not expected that frequent change of wedges will be required.

In addition to the sensitivity and gamma sections of the comparator wedge, two other densities have been added. The 0.30 density labeled "FG" in Figure 2 is used for determining maximum allowable fog and the 0.60 density labeled "DN" is used as a guide to insure that duplicate negatives are given sufficient exposure so that the densities of the original will be printed on the straight line portion of the characteristic curve.

Application to Control of Processing Solutions

The most elementary application of sensitometry to control of negative processing is achieved when a sensitometric exposure is placed on the end of each roll of film to be processed. This form of control gives information concerning the processing received for any specific roll, but due to variations in speed and contrast of different emulsions any changes which may occur in the processing solutions may be obscured. Some AF processing laboratories have adopted this technique since, in cases where the processed negative appears to be abnormal, the cause of the difficulty, whether it be processing or negative exposure, can be traced more readily.

A further improvement in sensitometric control can be achieved if several rolls of the same emulsion are set aside for check purposes. In this case a small section of the check emulsion, with a sensitometric exposure, is spliced into the rolls of film being processed. This method has been a standard technique in the motion picture field for many years. It has its limitations however, since variations in machine speed and developer temperature will affect the results, thus masking the variations due to the developer strength. Since many extra splices are required during the day, the possibility of a broken splice in the processing machine is increased.

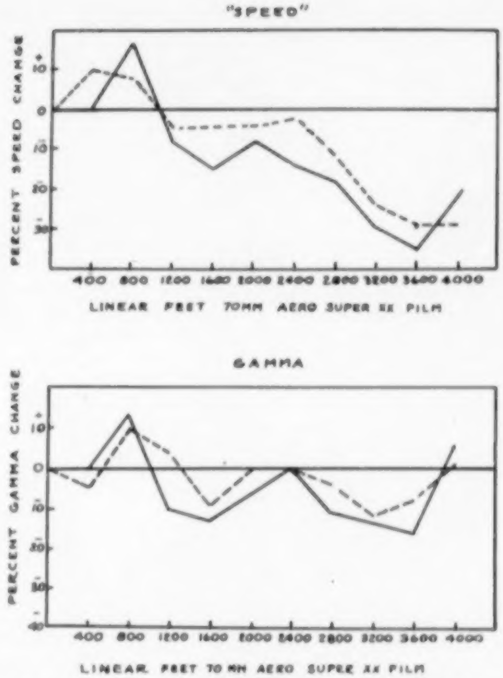

Fig. 4. Record of sensitometric determinations from film samples processed in a sensitometric "sink" using fresh developer (horizontal line, zero axis) and developer samples withdrawn at intervals from the continuous processing machine.

This may result in damage to valuable aerial film which has been obtained at great expense and at the possible risk of human lives.

A more promising approach for the control of solution strength is to withdraw samples of the developer from the processing machine and test them sensitometrically against a sample of the fresh developer. The sensitometric sink has been designed for this purpose. Since the test strips have been processed simultaneously in fresh and replenished developer, variations due to emulsions, temperatures, agitation, etc. have been automatically eliminated. Figure 4 shows a typical record from a run on a 70mm continuous processing machine. The linear footage of Type IB Class L 70mm film is marked on the horizontal, axis, and the percent change in "speed" and gamma during the processing run is marked on the vertical axis. The solid line represents the values obtained with the direct reading densitometer; the broken line represents the charted values for the same strips. The change in developer activity is noted by the downward slope of the "speed" and gamma lines. In this case an error in replenisher formulation, resulted in the gradual change in the "speed" and contrast of the developing solution.

Preparation of Duplicate Negatives

In the AF the duplication of reconnaissance negatives is a required task. In their preparation two specific requirements must be met if the duplicate negative is to

reproduce accurately the tonal rendition of the original negative. All the densities of the original negative must fall on the straight line portion of the characteristic curve for both the intermediate positive and the duplicate negative, and the development of the two must be such that the reproduction gamma is unity.[2] These conditions can only be met if sensitometric control is used.

To apply sensitometry to the production of duplicate negatives, a sensitometric exposure is first made on the film used for making the intermediate positive. After development the gamma is measured in the usual manner and the correct printing exposure for the positive is determined by comparing a highlight density with the density "DN" on the density comparator wedge. The intermediate positive is then printed on duplicating film and its development is adjusted so that the product of the gammas for the intermediate positive and the duplicate negative will equal unity. The depth of the duplicate negative is determined by comparing the lightest shadow area with the "DN" density of the density comparator wedge. If desired the contrast of the original negative can be altered on the duplicate by a deliberate change in development so that the product of the gammas is no longer unity.

Application of Sensitometry to Printing

Unlike the commercial photofinisher who obtains large supplies of materials from one manufacturer, AF units must contend with rolls of paper supplied by a number of suppliers. Since these papers may vary in speed by as much as two lens stops, an easy method for determining the emulsion sensitivity of papers is required. This may be accomplished, of course, by making prints on a sample of paper taken from each roll, but this method is both laborious and time consuming. A simple sensitometric test is considered easier to make and sufficiently accurate for the purpose.

After the correlation has been established between the sensitometric "speed" and the paper sensitivity setting on the printer the operator need only to expose a sample of the paper to the fourth-root-of-two sensitometric wedge previously described. The "speed" of the processed strip, is derived by selecting the last visible step before D Max as the "speed" point. Since four steps represent a double in "speed," it is possible to estimate the printing "speed" to the nearest quarter of a lens stop.

To establish a correlation between the printer and the sensitometric "speed" three basic steps are required. Once these steps have been completed no further calibration will be required until some change either in the printer or the processing conditions has occurred. The three steps are as follows:

1. A correlation between the sensitometric strips processed in the processing sink and those processed in the processing machine must be established. This step is necessitated by differences in rates of development for various manufacturers' papers. In Table 1, typical rates of development for two different papers are presented. Paper A develops much more slowly than Paper B, consequently the "speed" relationship between the two papers does not remain constant for all developing times. This improper correlation between the processing sink and processing machine will result in erroneous "speed" relationships.

Table 1

RATE OF DEVELOPMENT FOR PHOTOGRAPHIC PAPERS

Time of Development (Seconds)	Relative "Speed" Paper A	Paper B	Difference
45	1.25	4.00	2.75
60	2.00	4.00	2.00
75	2.75	4.25	1.50
90	2.75	4.25	1.50

2. The paper sensitivity calibration on the printer must be evaluated to determine what the markings mean in terms of actual photographic exposure. If this step has already been done by the printer manufacturer, it may be eliminated from the calibration procedure.

3. Lastly a calibration between the sensitometric "speed" and the paper sensitivity setting, common to all roll printers, must be made. This may be accomplished by making a series of prints at different paper sensitivity settings and developing them in the continuous processing machine. The paper sensitivity setting on the printer for the best print can then be related to the sensitometric "speed." In the case of variable contrast papers the prints should be made using a negative which best fits a No. 5 filter. With graded papers it will be necessary to establish a separate correlation for each grade of paper. This is required since the sensitometric "speed" measures the exposure required to reproduce the deepest shadow. When a graded paper is used which does not fit a test negative, detail in either the highlight or shadow area of the print must be sacrificed. Consequently sensitometric "speeds" correlated to one grade of paper will not indicate satisfactorily the printing "speeds" required for other grades of paper.

So far no mention has been made of a method for the simplified determination of contrast for photographic papers. Work is in progress to determine the type and extent of contrast measurement which will be required. This information has not progressed sufficiently to be included at this time.

Conclusion

This method of control is considered satisfactory for Air Force use. As soon as equipment becomes available and time permits it will be applied to all continuous printing and processing operations. Normally specific systems will be designed for any particular type of operation such as 70mm, $9^1/_2''$ aerial, film and 16 or 35mm motion picture film. It will be necessary to incorporate this system into AF training programs and to include it in the basic photography course for photographic technicians. This system has been developed under the cognizance of other branches of the Armed Forces and will be available for their use.

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